THE MANAGEMENT OF WINTER BARLEY AS A DUAL-PURPOSE CROP IN TASMANIA

by

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This thesis contains no material which has been accepted for the award of any other degree or diploma in any University, and to the best of my knowledge and belief contains no copy or paraphrase of material previously published or written by another person, except when due reference is made in the text of the thesis.

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ABSTRACT

A series of experiments were carried out from 1988 to 1990 at Thirlstane in North-Western Tasmania to determine the suitability of modern high yielding winter barley cultivars for dual purpose (winter grazing plus grain) management. The barley cultivar Ulandra (WU 3076) was used in the experiments. It has a prostrate growth habit and late flowering, characters which should make it suitable for use as a dual-purpose crop where growing points need to be protected during grazing.

In the first experiment sown in late April 1988, four grazing treatments were used, (i) control, no grazing, (ii) early grazing (as soon as a reasonable amount of forage was available), (iii) late grazing (just prior to the shoot apex reaching grazing height), (iv) early and late grazing (a combination of grazing treatments (ii) and (iii)). The grazing was carried out using Angus cattle to defoliate the crop as quickly as possible. In addition, small areas of each plot were mechanically defoliated, to assess whether cutting can simulate the effects of grazing. Immediately following the completion of the second grazing all treatments were split for nitrogen application of 0 or 50 kg N/ha, to determine its effects in assisting recovery following grazing.

The least amount of dry matter was removed by the early grazing and the most by the single late grazing. Nitrogen compensated for the loss of dry matter following early grazing, in that maximum dry matter and grain yield were brought up to the level of the nil N control. Nitrogen had no effect on late or twice grazed treatments, where maximum dry matter and final grain yield were greatly reduced. Grazing reduced final plant height by 15-20 cm. As the control treatment lodged, particularly with N application, the reduction in plant height could be considered to be an advantage. Cutting resulted in lower grain yields than grazing due to the greater severity of its effects on the growing crop.

In 1989 the experiment was repeated for a range of sowing times, late March, early April and late April. Wet weather in winter caused some problems with waterlogging, and as a consequence growth was reduced on all treatments. The late March sowing was the most affected as the worst of the waterlogging occurred at the time of grazing. The late April sowing was grazed in late August-early September during drier conditions and was therefore better able to recover from the effects of grazing. The early April sowing produced the largest amount of forage for all grazing treatments.

The late March and early April sowings grew rapidly in late autumn and early spring before the onset of the colder weather and produced more leaf area than the late April sowing, although none of the leaf areas were as high as might normally be expected. The late April sowing grew slowly up to the beginning of the warmer weather in early spring and whilst leaf area was always smaller than the other sowings, the crop appeared better able to utilise it in terms of final grain yield.

Grain yields for all treatments increased with later sowing, but all grain yields were well below the potential that has been shown for barley in previous years under Tasmanian conditions. All treatments in the late March sowing produced poor yields. The early and late April sowings produced similar yields for the control and the early grazing. In the early April sowing the effects of late grazing reduced the grain yields more than in the late April sowing.

Harvest index increased with both later sowing and heavier grazing. Numbers of ears and grains per ear were decreased by grazing but increased by later sowing date. Nitrogen assisted in recovery following grazing with higher grain yields for all treatments. It increased the number of ears, possibly due to increased tiller survival. Nitrogen fully compensated for the effects of grazing on the early grazed treatments. The grazing experiment was again repeated in 1990 using the early and late April sowing dates. Whilst growth and yield were better, the overall trends between treatments were similar to the two previous seasons. Nitrogen again assisted in crop recovery following grazing.

The results therefore showed that, with careful management, grain yield could still be satisfactory for crops grazed early, provided that conditions were not too wet during grazing and recovery was aided by adequate nitrogen nutrition. Sowing time appeared to be less critical than timing of grazing, which should be in relation to apex position and stage of development as well as when ground conditions are suitable.

Late grazing, or grazing twice, generally had a severe affect on recovery for grain yield, due to removal of the potentially most productive growing points as well as leaf area, and could only be recommended if winter forage was of greater value to a farmer than final grain yield.

Cutting, which tends to remove more leaf at the same defoliation height as grazing, is not an accurate method of predicting grain yields. However, it can be useful in predicting overall trends.

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LIST OF ABBREVIATIONS

DAS	days after sowing
HI	harvest index
K	potassium
L	leaf area index
LSD	least significant difference
N	nitrogen
PAR	photosynthetically available radiation

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INTRODUCTION

In Tasmania the use of cereals for dual-purpose (forage and grain) cropping has long been practised. Whilst traditionally oats have been the most popular of the cereals for this purpose, the low end value of the grain from oats could see a shift to other cereals such as wheat and barley.

There is a need to increase grain production as Tasmania is no longer self sufficient in this. The flexibility in a farming system that the use of barley as a dual-purpose crop offers, as well as the possibility of added value for the crop, means that there is potential to increase the area grown in the state and hence total grain production.

Cereals have also been shown to have great value as break crops in the intensive vegetable production systems now common in Tasmania. They are being increasingly grown for control of weed and disease in subsequent broad leaved crops, and for some improvement of soil structure and organic matter content.

In recent years high yielding dwarf winter varieties of cereals have been developed. These also have characteristics which may be useful for forage production. The winter barley cultivar Ulandra has been gaining recognition in Tasmania recently, mainly for grain production but some farmers have grazed it. It has a prostrate growth habit and is late flowering, characteristics which should enable the growing point to avoid removal during the period when grazing is likely.

This thesis examines whether a barley cultivar such as Ulandra can be successfully used as a dual-purpose crop. The amount of forage it is possible to remove by grazing and the effect of grazing on final grain yield were seen as important in determining its suitability as a dual-purpose crop. Therefore, Ulandra was sown on a range of dates in autumn and subjected to a range of grazing regimes. As crop recovery following grazing could be critical the role of nitrogen in this was examined. It was thought necessary to monitor crop growth and development closely, particularly the position of the apex in relation to grazing height.

This study used cattle for grazing, but because a large amount of previous work on dual-purpose cereals had been done using mechanical defoliation, a comparison was made to see if both methods gave comparable results.

CHAPTER ONE

LITERATURE REVIEW

Tasmania is generally characterized as being in the high rainfall zone of Australia (Williams, 1985; Davidson et al. 1985). Due to a combination of adequate moisture and low temperature most of Tasmania also has a long, i.e. greater than 9 months, growing season (Davidson, 1985). This reliable climate would appear to make Tasmania ideal for cereal production, however due to a number of factors this potential has largely been neglected.

In the early part of the 19^{th} century not long after settlement, Tasmania was the major source of grain supply for the rest of Australia. The development of machine harvesting of grain, which favoured areas where the harvest could be carried out in dry weather, followed by the expansion of the railways saw the main grain growing area in Australia expand inland away from the high rainfall zone (Davidson, 1985). This century has seen a great decline in grain production in the high rainfall zone of Australia with production shifting to what is termed the "wheat-sheep" zone.

In the past 50 years wheat production in Tasmania has declined from major crop status to insignificance (Wade, 1988). Barley is the only cereal crop to have increased in Tasmania in that period, having increased sixfold from 1930's production levels. The increase in barley production can be accounted for by expansion of the brewing industry and the release of higher yielding cultivars suitable for both malting and feed (Wade, 1988).

Cereals have been a poor relation in terms of grower return in comparison to other crops in Tasmania in recent years. A ranking of gross margins for crops on the North-West coast of Tasmania in 1987-88 (Miller & Jarosz, 1987) placed malting barley 16^{th} and wheat 17^{th}. The difference in monetary terms was quite significant with the top 10 rankings returning over $1000 per hectare more than malting barley. Even crops such as poppies which may be expected to compete with cereals for cropping area in less heavily cropped regions of the state showed considerably higher returns per hectare. However these figures were based on cereal yields of 2.8t/ha. It has been shown that yields of cereals in Tasmania between 7.5t/ha (Terry,1987) and 12t/ha (Mendham & Russell, 1987) can be achieved.

1.1 Winter Barley

Barley has the flexibility to be grown as either a short season (spring sown) or long season (autumn or winter sown) crop. Several factors can make a winter barley more attractive to grow. These include a longer cooler growing season and the alleviation of the risk of moisture stress in a shorter growing season.

Long season (winter) barley cultivars will tend to have different characteristics to spring cultivars. A winter barley has been described as one capable of overwintering in its normal area of cultivation (Jenkins et al, 1976). A normally accepted definition is that a winter variety has a vernalization requirement. Other attributes may include a prostrate juvenile habit, frost resistance and sensitivity to short days.

Barley has two distinct end uses; for feed and for malting. Malting barley needs to be low in protein whereas feed barley is preferably high in protein. For this reason the production systems and cultivars used may be different. As a long season or winter cereal, barley will most likely be high in protein, therefore winter barleys would be best developed as feed barleys. However ways of manipulating the protein level in the grain of long season barley may be worthy of further investigation.

1.2 Dual-purpose cropping

In the high rainfall areas of Australia winter cereal crops will compete for land with grazing animals. Cannon (1974) found clean wool production per head to decline linearly with the proportion of land sown to crop, due to the increased stocking rate on the uncropped land. There is a need to integrate crop production with livestock enterprises (Reeves, 1988) rather than treating each enterprise individually, as the majority of mixed farms are not producing at their true potential.

One way of doing this is the use of dual-purpose cereal crops, that is the winter grazing of a cereal followed by a grain harvest. The cereal crops will have a substantial amount of nutritious dry matter available at a time when growth of pastures has almost ceased due to cold weather (Dann et al, 1983). With the correct choice of cultivar and appropriate management, winter grazing could be carried out without significant loss in subsequent grain yield.

Dual-purpose crops can supply high-quality forage which is likely to exceed the nutrient requirements of grazing livestock (Horn,1985). In a comparison between cereals and other forage crops including rape, lupins, and peas, Dann et al (1977) concluded that cereals showed the greatest potential for use as dual purpose crops and of these oats and barley were better overall. In the cooler regions of Australia the use of cereals as dual purpose crops is widespread (Hoogvliet and Wheeler, 1977).

Some of the perceived advantages for farmers include reducing excessive vegetative growth which may promote lodging (Dann, 1968), the alleviation of real or supposed winter feed deficiencies, improved nutrition at critical times in the breeding cycle of livestock, and to act as a stage in pasture re-establishment (Hoogvliet and Wheeler, 1977). Cereals with their higher forage production than other grasses can be a valuable source of supplementary feed during the winter months when growth is slow. It is also possible, if grain yield is not substantially reduced, that grazing can add extra value to a crop.

Traditionally in Tasmania, oats has been used as the major dual purpose crop although it has been recently suggested (Abdul-Rahman et al, 1987) that barley, as the most widely grown cereal in Tasmania, could also be successfully used as a dual purpose crop.

Abdul-Rahman (1988) concluded that it is important to know for a dual purpose crop:

i) the position of the apex below the soil surface during early stages of development when grazing is required

ii) the timing of the rise of the apex above the soil surface, to estimate the safe grazing period.

However residual leaf area index (L) after defoliation can also be important as it is significantly correlated with grain yield (Abdul-Rahman, 1988), and is therefore also important.

It has been established that heavy grazing can decrease grain yield (Dann et al, 1977), however a dual purpose crop may be more profitable depending on the economic conditions at the time. The farmer has many options open, between heavy grazing and low grain yield, and light grazing and relatively higher grain yield, the choice will be his depending on what he most values. The crop could be treated as a forage crop with the added bonus of a final grain yield or as a grain crop with the bonus of some extra forage.

1.3 The value of barley as forage

Cereals have been shown to have advantages over pasture as forage crops. Dann et al (1974) compared oats versus pasture for sheep. Greater ewe weight gains per head and per ha were obtained in both years on oats. Gains in reproductive performance of the ewes however were small or negligible. Day et al (1968) suggested that barley forage be considered as an economic source of protein .

Cereal forage is lush, high in protein and low in fibre during most of the growing season. There is however a danger of grass tetany close to calving which may be because Ca rather than Mg is deficient (Bohman et al, 1983). Bloat can also be a problem (Horn & Frost,1982). Cereal forage is high in N content which makes it excellent for grazing, however recently fertilized barley can lead to a risk of nitrate poisoning (Wright and Davison, 1964).

In comparing the *in vitro* digestibility of forage crops Lovett and Matheson (1974) concluded that the difference between cereals was small. However, more recently Cherney and Martin (1982a) found that barley forage had higher in vitro digestibility and lower cell-wall content, acid-detergent fibre, and acid-detergent lignin than that of wheat, triticale, or oats. However digestibility decreased with increased maturity due to increased stem lignification (Cherney and Martin, 1982b).

1.4 The importance of Leaf

Leaf area is the critical factor in maximising the amount of photosynthetically active radiation (P.A.R.) absorbed by the plant. The amount of P.A.R. available to the plant affects grain yield by determining assimilates available for crop growth. The fraction of radiation intercepted by a crop depends mainly on its leaf area index (L) (Shibles and Weber, 1965). For most crops when L reaches 4-5, more than 80% of the incident PAR will be intercepted by the leaf canopy (Biscoe and Gallagher, 1975).

When grazing a winter cereal crop enough leaf needs to be removed for worthwhile animal production while retaining the capacity to regenerate a full canopy for light interception in spring.

A reduction in L has been shown to reduce grains/ear, mean grain weight and rate of development of the shoot apex in wheat (Davidson, 1965).

1.5 Effect of grazing on grain yield

Over the years many researchers have reported on the effect of grazing on various cereal crops with a wide range in effects in final grain yield,from an increase (Dann et al, 1977; Sharrow and Motazedian, 1987; Day et al, 1968), through no effect (Aase and Siddoway, 1975; Winter and Thompson,1987), to a decrease in final grain yield (Sprague, 1954; Pumphrey, 1970; Dunphy et al, 1982; Morris and Gardner, 1958). The variation can be accounted for by a number of factors including experimental method, growth stage when grazing occurred and intensity of grazing.

Grazing early in the growing season appears to have no significant effect on final grain harvest (Aase and Siddoway,1975; Winter and Thompson,1987). However delaying the date of initial forage removal can lead to a decrease in final grain yield (Aase and Siddoway,1975; Winter and Thompson,1987; Pumphrey,1970; Dunphy et al ,1982). A progressive reduction in final grain yield can occur in wheat with a progressive delay in grazing date (Dunphy et al, 1982). Grazing late, i.e. in the vegetative growth stage, has been found to reduce grain yield in wheat more than grazing for the entire grazing period (Pumphrey,1970).

Many reasons have been given for the decrease in grain yield. Dann (1968) reported that a reduction in grain yield in clipped wheat was due to a reduction in average seed weight rather than seed number. Dunphy et al (1982) reported a reduction in seeds per head. A reduction in the amount of photoassimilate for final grain fill may be the problem due to removal of leaf area.

However more recently Abdul-Rahman et al (1987) working with barley in Tasmania suggested that damage to or removal of the shoot apex from the main stem and primary tillers during grazing may be the main cause of yield reduction. This would leave the grain yield to be carried on weak secondary tillers.

Dunphy et al (1984) found that when leaf area produced during vegetative and jointing stages was harvested as forage, grain yield in wheat was limited by the potential of the plant to rapidly produce new leaf area and prevent tiller senescence during the period between jointing and anthesis.

Winter and Thompson (1987) have compared a grain only system with grazing of semi-dwarf wheat using different sowing times for grain only and grazing. In each of 3 years grain only had a greater grain yield potential and growth, however the grain yield potential of the grazed wheat was also high if grazing was terminated early. Grazing delayed heading and decreased grain yield due to limiting L during the spring recovery period. More recently similar results have been shown with barley in Syria, where grazing reduced straw and grain yield (Yau et al 1989b), and delayed heading and maturity (Yau et al 1989a).

Increases in grain yield following grazing occur in situations where the crop is susceptible to disease or lodging (Dann et al,1977; Abdul-Rahman et al, 1987), and where anthesis is delayed into the frost free period. Grazing decreases lodging as it tends to decrease the final plant height (Pumphrey, 1970; Winter and Thompson, 1987). However Winter et al (1990) working with wheat concluded that grazing is more likely to reduce the yield of a lodging-resistant short cultivar with high yield potential than a tall cultivar that is susceptible to lodging.

Root-rot effects are correlated with heading date in dwarf wheat, late heading crops being more severely affected. This lowers grain yield only in relation to a late grazing termination (Winter and Thompson,1987).

The removal of excess leaf area also reduces the risk of infection by disease spores. Grazing has been shown to reduce fungal disease in barley (Ralph, 1984), presumably by reducing inoculum levels and also reducing humidity in the lighter canopy. Herbicide usage on grazed wheats will increase yield, as weed competition is likely to be serious.

1.6 Grazing timing and intensity

A great deal of work has been done concerning the timing and intensity of grazing. Timing has more relevance if it is compared with the stage of development of the barley crop rather than calender time. Aase and Siddoway (1975) have shown that winter wheat can tolerate severe physical damage through the tillering stage without a significant decrease in grain production, but destroying the leaf during stem elongation results in a definite and progressive reduction in grain yield. Intensity of grazing whilst depending on the farmers judgement refers to the amount of forage removed by the animals.

The conclusions from the results of many workers in winter grazing or clipping are that:

i) increases in grain yield normally occur only when lodging would take place if the crop were not grazed.

ii) under conditions of average or low soil fertility losses in yield may be expected to result from grazing.

iii) effects of grazing are more severe later in the growing season. (Aldrich, 1959).

Delaying the final forage harvest has been found to lead to a progressive reduction in grain yield in wheat and a decrease in tiller survival, fewer seeds/head but little effect on the average weight per seed (Dunphy et al, 1982). Winter and Thompson (1987) found that grazing wheat past the period of initial elongation of the first internode delayed internode elongation. Abdul-Rahman (1988) working with barley grown in Tasmania found that delaying the final forage harvest reduced all yield components.

With spring barley Day et al (1968) found that each successive clipping reduced plant height, one clipping reduced lodging, 2 or more eliminated lodging. Therefore it would seem reasonable to conclude that increasing the intensity of grazing will reduce lodging.

A light grazing is likely to have minimal effect on final grain yield, however heavy grazing can severely reduce final grain yield leaving the plant to rely on root reserves for recovery. Dann et al (1977) showed crash grazing, i.e. removing available forage in the shortest possible time, to severely reduce the final grain harvest in wheat. A rotational grazing is generally even more damaging (Dann et al,1974)

Several researchers have shown deleterious effects on both the crop being grazed and the soil from continuous trampling by livestock. Warren et al (1986) found that infiltration rate decreased significantly and sediment production increased significantly on a soil devoid of vegetation following periodic trampling. Deleterious impact increased as stocking rate increased. Damage was augmented when the soil was moist.

Aase and Siddoway (1975) simulated the most severe effects of defoliation on subsequent regrowth and production by clipping of winter wheat in spring at ground level. There appeared to be a dependence on root reserves to initiate and support regrowth. Little other work has been done on the role of root reserves in assisting plant recovery. However Trent et al (1988) working on the roots of wheat found that ungrazed plants have an enormous carbohydrate pool during grain filling that grazed plants never match even with longer retention of leaves. This would be an area well worth examining in barley.

If a crop is grazed late this will increase dry matter available for animals. However late defoliation probably decreases the level of photosynthetic activity and assimilate distribution before anthesis, thus reducing number of grains per spike and weight per grain (Dann, 1968) and thus final grain yield.

1.7 Position and Development of the Shoot Apex

Yield of a barley crop is the final grain weight per unit area, which is the product of grain number and individual grain weight. Both grain number and grain weight will be influenced primarily by available assimilates, which affect these factors by determining the number of heads and the number of spikelets per head for each unit area. The components of grain yield are determined in a predictable sequence over time, which is number of tillers, number of fertile heads, number of spikelets per head and finally weight per seed (Sharrow & Motazeiden,1987). In determining the effect on yield components of grazing the stage of apical development, position of the shoot apex and the extent of tillering are important.

Kirby and Appleyard (1984) list the stages of apical development as:

1) vegetative, 2) double ridge, 3) triple mound, 4) glume primordium, 5) lemma primordium, 6) stamen primordium, and 7) awn primordium

During the vegetative phase leaf and root growth, and tillering predominate (Evans & Wardlaw,1976). The double ridge stage marks the onset of ear initiation (Deitzer, 1985), which is the start of the reproductive phase. The reproductive phase extends through to anthesis and determines the size of the sink available for assimilate.

During ear initiation the number of primordia increase at a rapid rate and reach a maximum at the onset of stem elongation. Appleyard et al (1982) found the duration of the ear initiation phase to be negatively correlated with the duration of the ear growth phase , making the growth cycle fairly constant. The duration of the ear initiation period is responsible for the variation in the maximum number of primordia formed, and it is correlated with the number of leaves as is the length of the life cycle from sowing to anthesis.

The shoot apex of barley does not rise above the soil surface until the beginning of rapid stem extension and the tiller apices will move upwards between 1 and 3 weeks later (Hay, 1978). In fact the elongation of the first internode is a good indicator of the cessation of spikelet formation and the onset of strong stem growth (Kirby, Appleyard & Fellowes, 1985). The number of primordia decline during ear growth, stabilising at anthesis. The causes of this are not yet fully understood but relate to competitive stresses within the plant, and adjustment to a number able to be carried through to maturity.

The position of the shoot apex is an important consideration when grazing, as removal can severely reduce yield. Abdul-Rahman (1988) studied the position of the shoot apex in barley and its effect on grazing in both erect and prostrate barley cultivars. He found that the rapid winter growth of erect barley cultivars provided substantial amounts of dry matter for winter grazing. However, the shoot apices on the mainstems of these cultivars developed rapidly below the soil surface and emerged above ground level as much as 6 to 8 weeks before those of the prostrate cultivars, thus curtailing the "safe" period for grazing. Early defoliation which removed most of the biomass retarded the increase in apex height of all barley cultivars and apices of all cultivars followed a sigmoidal curve of apex elongation. The decreased growth rate of ears was offset partly by a longer period of growth and delayed ear emergence. Abdul-Rahman concluded that his results support the theory that defoliation encourages tillering by removing apical dominance.

Gallagher et al (1975) found that grain yield in the spring barley varieties they studied depended mainly on the grain number per unit ground area which a crop is able to produce. An important component determining the grain number per unit ground area is the number of ears per unit ground area and this places importance on tiller number and survival.

Sharrow and Motazedian (1987) found that components of grain yield in wheat that are largely determined at phenological stages prior to tiller elongation may respond positively to grazing management, work being needed on the effects on individual components. They showed that grazing increased yield due to an increase in the number of fertile spikelets per head. There was a possible reduction in tiller number due to increased tiller mortality.

Yau et al (1989a) found that with barley, grazing encouraged tiller production but reduced head number because of higher tiller mortality or infertility. Seeds/head and individual grain weight, however, were unaffected. Grazing also delayed heading and maturity and reduced plant height.

1.8 Simulated grazing

Many experiments have used a form of clipping or mowing to simulate the effects of grazing, the advantage being that it is easier to carry out. This can be a disadvantage in that it fails to take account of the effects of selective grazing, trampling and return of nutrients to the crop. Various techniques have been tried to overcome this including the return of clippings. Working with pasture, Cuykendall and Marten (1968) concluded that if clipping is used to simulate grazing extremely high levels of K and N must be applied to compensate for the effects of animal excreta. Pumphrey (1970) in a comparison between clipping and grazing wheat found that each method reduced grain production and he concluded that clipping simulated grazing within the limits of humans to estimate when and how much forage to remove.

More recently Abdul-Rahman (1988) compared the effects of cutting and grazing with sheep on oats and barley in Tasmania. He found that the sheep had grazing preferences, grazing oats before grazing barley when presented with both at the same time. A larger proportion of the dry matter and L of erect cultivars were removed by cutting than grazing, and grazing did not damage the shoot apices while cutting did. However defoliation height was not as uniform with grazing as with cutting.

Abdul-Rahman postulated that residual leaves after cutting may be less photosynthetically effective than those after grazing. The amount of leaf removed or remaining after early cutting may not be closely correlated with that after early grazing.

Working with barley in Syria, Yau et al (1989a) found that simulated and actual grazing to the same height produced similar effects on the different characters investigated.

1.9 Animal effects

Grazing a cereal crop will subject it to various animal influences, however most work on animal effects has been done on pastures. Matches (1968) identified the following animal factors as having an effect : manner of defoliation, trampling, selective grazing, and the return of nutrients through animal excreta. Matches found little effect of urine return. The grazing behaviour of sheep influenced uniformity, therefore it is essential to have an adequate number of sheep. This is not so with cattle.

Wheeler (1958) examined the effect of sheep excreta and nitrogenous fertilizer on the botanical composition and production of a ryegrass/clover ley. Urine and dung were returned in 4 treatment combinations, comprising no dung or urine, dung, urine or both as well as four fertilizer nitrogen (N) treatments. Urine restricted the incursion of weed grasses. Combined with urine or full return of excreta high levels of applied N increased herbage production by up to 120% with little response to dung except at highest N. The yield response to applied N was almost linear, but in the absence of animal returns the response was poor, partly due to shortage of potash since potassium (K) was removed in the herbage. Herriott et al (1959) showed that K returned to the soil by urine is readily available. Wolton (1963) found that N in the excreta appeared the major factor in increasing forage yield in a pasture. Therefore a large part of forage yield can depend on nutrient return from animals.

It may be possible to develop a system of grazing of cereals that assists the crop through nutrient return, however a crash grazing would not do this as it would act to mine nutrients. The likelihood is that any grazing of cereals will have the net effect of removing nutrients, even after considering returns; therefore the crop will need sufficient reserves to assist its recovery after grazing.

1.10 Cultivar

Some of the work reported on grain yield reduction from grazing of cereals may be the result of incorrect choice of cultivar. Pumphrey's (1970) results show that a semi-dwarf winter wheat utilizes all its spring vegetative growth to produce maximum yield therefore any removal results in decreased grain head and straw production. Dwarf and semi-dwarf cultivars of any cereal are bred for purely grain production, so special cultivars may be needed for dual purpose use.

Dann et al (1977) postulate that if the association between delayed reproductive development of winter wheat and slow winter growth could be broken, such a crop because of its usually high grain value would have obvious advantages such as stability of grain yield under grazing.

In reviewing work on the effects of grazing on the shoot apex in grasses and its importance in grassland management, Booysen et al (1963) concluded that 3 main points required detailed investigation:

i) the time of elevation of the shoot apex and the duration of its accessibility to the grazing animal.

ii) the capacity of the species for producing reproductive tillers (ratio of reproductive to vegetative tillers).

iii) the capacity of the plant to produce lateral tillers from axillary meristems.

In an experiment with grazing of several cultivars of barley Abdul-Rahman et al (1987) found the highest forage yield with erect cultivars, and the highest grain yield in prostrate cultivars. Erect cultivars were disadvantaged by defoliation when the growing points were removed. It would appear that the choice of cultivar would depend on what the main purpose of the crop was, either forage or grain yield.

The encouragement of tillering would be an advantage in a grazed cultivar especially if grazing removed the main stem. Richards (1983) found that longer leaf area duration and improved light penetration resulted in more fertile tillers in wheat. MacDonald (1990) found tillered barleys to out-yield uniculm ones.

To maximize grain yield after grazing a dual-purpose barley ideotype would have a prostrate habit and free tillering as well as having an early sowing capability, usually meaning a winter habit although a strong daylength response may have a similar effect.

1.11 Agronomy

With dual-purpose crops, the recommended seeding date is 3 to 4 weeks earlier than for grain production alone (Sithamparanathan, 1979a; Ralph, 1984). This is to allow for maximum early growth before cold weather reduces growth, so that there is adequate forage available in winter. Rapid achievement of near full light interception will lead to maximum growth rate and carbohydrate reserves in the stem and roots. Pests and disease can be problems associated with early sowing (Sithamparanathan,1979b) therefore it is recommended that the seeding rate be increased 50-100%. Ralph (1984) recommends that seed rates should be increased if the crop is to be grazed. Because it is recommended that dual-purpose crops are sown earlier than grain only crops, a comparison between the two systems is difficult.

It may be possible to compensate for nutrient loss from grazing and also assist with plant recovery by the application of nitrogen (N) fertilizer. N is the principal fertilizer needed for cereals (Burton and Prine, 1958), an autumn application being possibly the most important. Looking at barley as a grain only crop, Birch and Long (1990) found that N increased dry matter and grain yield, total tiller number and the number of fertile tillers. Others have found that nitrogen increased leaf extension rate (Maan et al, 1989), stem production and grains/ear (Pettersson, 1989) in barley.

N fertilizer has been shown to be effective in maintaining grain yields of oats and rye clipped till late winter (Morris and Gardener, 1958) and the N content of forage was increased by higher N fertilizer. N fertilizer applied to grazed pasture has also been shown to increase the weight gain of sheep (Wilson et al,1966), because of the extra feed available. Colman (1966) believed that high forage yields cannot be sustained without additional N later in the year.

Abdul-Rahman (1988) on work with oats grown in Tasmania demonstrated that N applied following grazing can increase total dry matter production and grain yield. Further investigation on the role of N in the recovery of dual-purpose crops is needed.

1.12 Conclusion

Barley forage is high in protein and can provide a valuable supplementary feed in winter when pasture growth is slow. Grazing could also provide added value to a grain crop provided the reduction in grain yield was not great. Some farmers, however, may view the grain yield as a way of adding extra value to a forage crop. In either case it will be essential to find ways to maximise final grain yield within the limits of forage requirements.

Grain yield will not be drastically reduced by grazing if the grain yield potential can be maintained. This necessitates the plant having sufficient time and reserves to assist recovery from grazing. Sufficient time means that the crop should be sown earlier than a grain only crop. The amount of reserves available will depend to some extent on the storage capacity of the stems and roots of the plants, however there may be several other ways of ensuring sufficient reserves, for instance ensuring that there is adequate leaf left after grazing to enable the plant to capture incoming radiation. Alternatively nitrogen fertilizer or possibly potash could be added to the crop to give a quick recovery.

In ensuring that yield potential is maintained it is also important to avoid damage to the shoot apex by keeping it below grazing height, that is by ceasing grazing before it reaches this level. The time taken for this to happen can be extended by the use of cultivars with winter type and/or prostrate habits. It has also been shown that commencing grazing earlier will lengthen the time it takes for the shoot apex to rise. Much work has yet to be done on the effects of grazing as previous work has often simulated grazing by cutting. Stock may have different effects on the crop than cutting does.

Areas of research that still need further work include the effects of N and other fertilizers in assisting crop recovery, different intensities and timing of grazing, and the effects of different sowing times on the crops performance.

CHAPTER TWO

THE EFFECT OF GRAZING AND CUTTING ON FORAGE AND GRAIN YIELD, AND THE USE OF NITROGEN IN RECOVERY FOLLOWING DEFOLIATION, OF WINTER BARLEY IN TASMANIA

The work of Abdul-Rahman (1988) suggested that barley could be successfully used as a dual-purpose crop. He proposed that a prostrate winter barley was the ideal type for winter grazing. The next step would be to examine the effects of grazing on a dual-purpose barley cultivar grown under field conditions. To do this an experiment was carried out using the new winter barley cultivar, Ulandra, with the following objectives in mind.

(i) To study the effect of timing and number of defoliations on forage and grain yield of winter barley.

(ii) To examine whether nitrogen can assist crop recovery following grazing.

(iii) To compare grazing with cutting as a method of assessing the effects of defoliation.

2.1. Materials and Methods

2.1.1. Experimental site

A 0.8 ha plot was selected at Thirlstane (latitude 41° 51′ S, longitude 146° 32′ E, elevation about 40 m) on the North-West coast of Tasmania. The soil type was a krasnozem (red basalt) commonly found in this area (Wade, 1988). The site had previously been sown to pasture for as long as records were available.

2.1.2 Cultivar

The barley cultivar used was Ulandra (WU 3076), a two row winter feed barley bred in England and introduced to Australia through Western Australia (Read and Macdonald, 1987). Ulandra has a prostrate growth habit and late flowering, which should lead to the opportunity for the greatest potential grain yield following defoliation (Abdul-Rahman et al. 1987). It has excellent head and grain retention, and the straw is strong and of medium height which should make lodging unlikely.

Ulandra is intolerant of high aluminium levels in acid soils, it is susceptible to temporary yellowing in winter, and it requires vernalization (Read and Macdonald, 1987).

2.1.3 Site preparation and Sowing

The site was ploughed a month before sowing and then cultivated the day before sowing. The crop was sown on 25/4/1988 at a seeding rate of approximately 125 kg/ha. The crop had fully emerged by 8/5/1988, resulting in about 108 established plants/m^2. The low establishment rate was most likely due to a rough seed bed. The crop was sprayed with M.C.P.A. at 1 l/ha to control broadleaf weeds on 4/6/1988.

2.1.4. Experimental layout.

The main experiment was laid out on a split-plot design with different grazing regimes as the main treatment. The following main treatments were applied to each of 3 replicates:

(i) control - no grazing
(ii) early grazing - 102 days after sowing
(iii) late grazing - 145 days after sowing
(iv) early and late grazing - a combination of treatments (ii) and (iii).

Early grazing was carried out as soon as it was determined that there was sufficient forage. Late grazing was carried out at a time determined to be just prior to the shoot apex reaching maximum height for safe grazing.

Each plot measured 40m x 10m. Angus cattle (cows and calves) grazed the plots, the plants being grazed to a height of about 4 cm as quickly as possible, i.e. within 2-3 hours for each plot. Each plot was fenced and grazed separately with the use of portable electric fencing. (plate 1)

The early (initial) grazing was delayed due to wet weather and was eventually carried out between 6/8/1988 & 7/8/1988. The late (final) grazing began on 16/9/1988 and finished on 18/9/1988, the cattle remaining on the plots longer due to the larger amount of available forage.

To determine whether nitrogen can assist recovery following grazing, the plots were split for nitrogen application. 250 kg/ha of Sulphate of Ammonia was applied to half of each plot immediately following the completion of the late grazing. This gave a nitrogen rate of 50 kg /ha.

2.1.5. Cutting

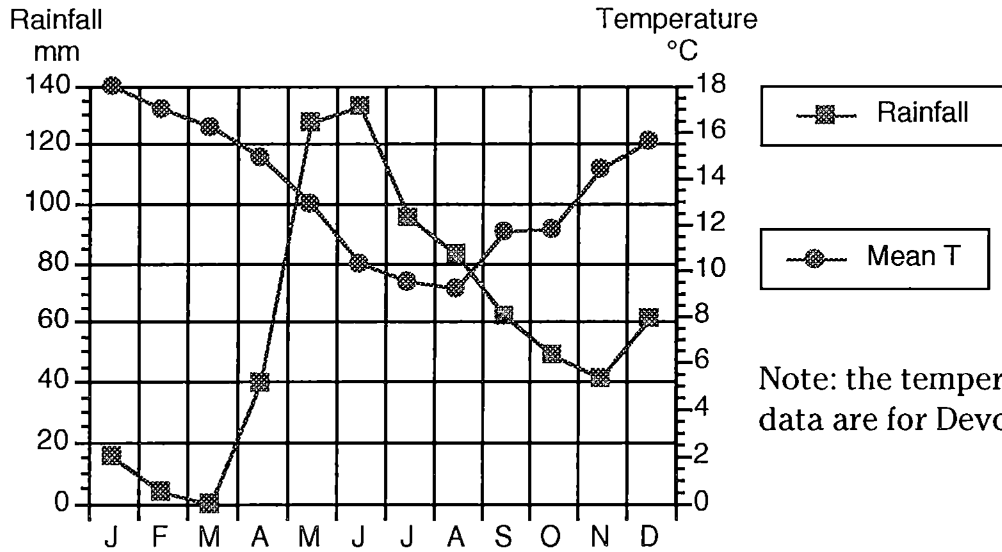
To assess whether the effect of grazing can be simulated by mechanical defoliation, hence allowing prediction of grazing effects from small scale experiments without the cost as difficulty of grazing, a $1m^2$ sub-plot was selected at random in each of the grazed with nil N plots . This plot was isolated with electric fencing to prevent interference from the grazing cattle (plate 2.1). Immediately after the plot was grazed, the $1m^2$ sub-plot was cut with a brush cutter to a height judged to be the same as that of the grazing.

2.1.6. Climate

Weather data recorded for the area in 1988 are shown in figure 2.1 (page 14). When the sowing occurred in late April the ground was still relatively dry. However good rains occurred in May and June. Wind and rain in December and early January caused lodging in the control treatments due to their greater straw length (plate 2.2).

A problem encountered with several of the treatment plots was that of waterlogging which reduced growth of the crop noticeably. The affected barley also had greater difficulty recovering from defoliation than the other treatments.

Figure 2.1. Monthly rainfall and mean temperatures for the area in 1988



Note: the temperature data are for Devonport.

2.1.7. Sampling

Samples of 0.5 m^2 were taken of all treatments before and after each grazing, as well as at intervals during the period of growth up to the time of maximum dry weight. All samples were separated into stem, leaf, ears, dead matter and weeds and dried at 70° C for at least 48 hours to determine dry weight. Leaf area was also recorded on a sub-sample for each sample. Forage removed was also recorded for the cutting sub-plots. Periodic measurements were made of the height of the shoot apex during the early stages of crop growth.

At harvest, a sample of 0.5 m^2 was taken from each plot and from the cutting sub-plots. From these straw and ears were separated and the number of ears were counted. Straw length was measured along with straw dry weight. The ears were threshed to remove the grain which was then dried. From this, grain yield, grain number per ear, grains/m^2, and individual grain weight were calculated.

Machine harvested yields were calculated by harvesting a strip, 1m wide by 10m long, from one replicate of each of the different grazing treatments. A small plot harvester from the Tasmanian Department of Primary Industry was used for this. Water-logged patches in the other two replicates made it difficult to select a large area for machine harvest, so most reliance was placed on the hand-harvested samples.

Grain samples taken from the machine harvested plots were used for measuring nitrogen content, which was determined by the Tasmanian Department of Primary Industry using an adaption of Kjeldahl's method (Vogel, 1961; Keay and Menage, 1969). Protein was calculated using the normally accepted formula, protein = nitrogen x 6.25 (anon. 1990).

2.1.8. Statistical Analysis

A split plot analysis of variance as outlined in Steel and Torrie chapter sixteen (1981), was done for forage yield, maximum dry matter, grain yield, straw length, harvest index, and each of the yield components. The example for grain yield can be found in appendix A. Least significant differences (lsd's) are included on figures in this chapter only when the results are statistically significant.

plate 1.1 A general view of the plots, following the first grazing.

plate 1.2 A comparison between ungrazed (left) and early grazed (right) plots prior to the late grazing.

plate 2.1 Cut plots were isolated with electric fencing to prevent interference from the grazing cattle.

plate 2.2 The control plots lodged just prior to harvest, due to the greater straw length.

2.2. Results and Discussion

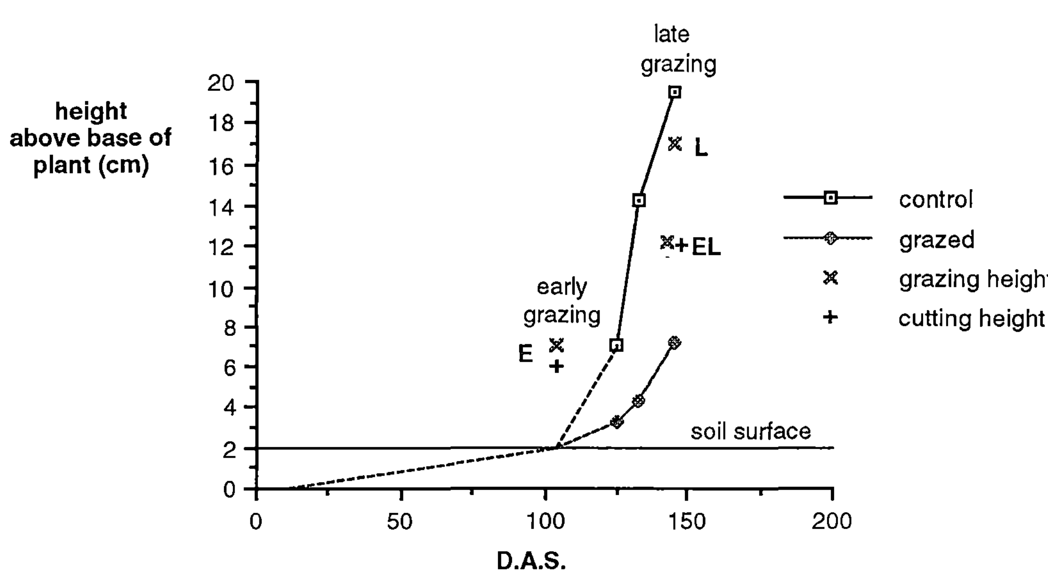
2.2.1 Height of apex

The height of the shoot apex above the base of the crown, relative to time after sowing is presented in figure 2.2. The position during early growth was estimated using data from subsequent experiments and the stage of development as guides. The height at which defoliation occurred for both cutting and grazing is shown on the graph.

The height of the first grazing and cutting were similar, both being well above the shoot apex which at this stage had not risen above the soil surface. Grazing height for the late grazing differed to that for the early/late treatment (figure 2.2). Both late cutting treatments and the second grazing of the early/late treatment were at a height of 10cm above ground level while the single late grazing was at a height of 15 cm above ground level. As a result more forage was removed by cutting than grazing for the late defoliation treatment (figure 2.3), and it may be assumed that cutting would have removed more of the shoot apices than did grazing.

Defoliation slowed the rate of elongation of the shoot apices (figure 2.2), which is in agreement with the findings of Abdul-Rahman (1988), however apical development for all treatments was similar at the time of the second defoliation, the shoot apices being at the awn primordium stage. Only in a waterlogged patch were plants found with shoot apices still at the stamen primordium stage. The slower rate of elongation in the early/late treatment meant that although the height of the second grazing was below that in the single late grazing treatment it was never the less still above the height of most shoot apices.

Figure 2.2. A comparison of cutting and grazing heights with height of main stem apex above the base of the crown. Dotted line indicates estimate.
E = early grazing, L = late grazing, EL = late grazing of early/late grazing

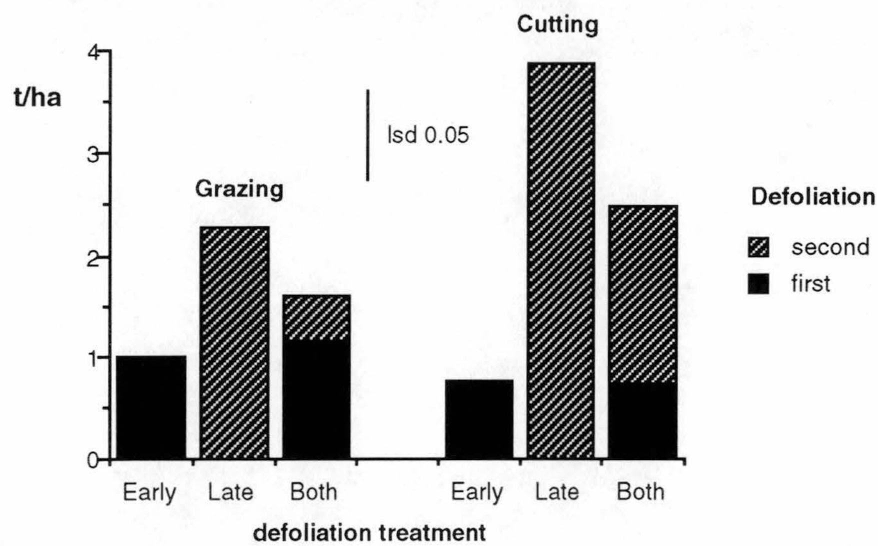


2.2.2 Forage removed

Forage removed by grazing was estimated by subtracting dry matter remaining after grazing from dry matter prior to grazing. Forage removed by cutting is simply the total dry matter removed.

More forage was removed (fig. 2.3) by a single late grazing than with both grazings of the early/late grazing treatment, indicating that the rate of dry matter production in the early/late treatment was reduced following early grazing. Cutting yielded more forage than grazing in the late defoliation of both early/late and late treatments. The reason this occurred with the early/late treatment cannot be attributed to a difference in defoliation height, but rather to a wastage of feed by the grazing cattle. This was observed, and also there was an increase in the amount of dead matter in samples from grazing plots following the second grazing. There was a tendency for the cattle to trample and flatten the crop rather than eat it, especially when there was a large amount of feed available.

Figure 2.3; Total amount of forage removed (t/ha) by both grazing and cutting for all defoliation treatments. Bar indicating LSD is for between defoliation treatments.

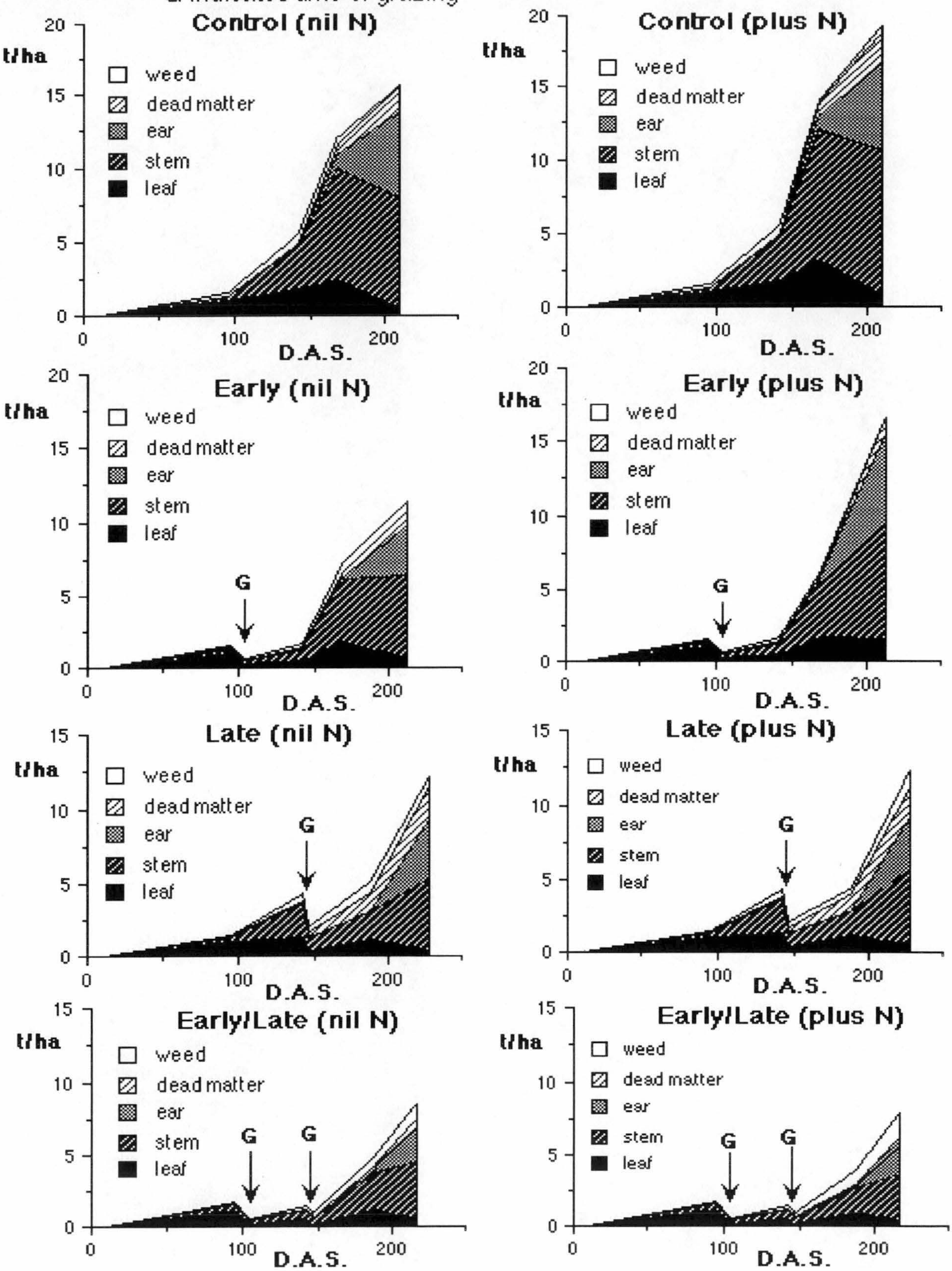


2.2.3. Change in plant dry matter

With the early grazing and early/late grazing treatments most of the forage removed by the cattle was green leaf, however at the single late grazing stem accounted for a greater proportion of forage removed (figure 2.4).

Change in plant dry matter with time was only recorded for the grazing treatments. Up till the time of the first grazing at 103 and 104 days after sowing growth was slow with most of the dry weight being green leaf (figure 2.4). After the time of the first grazing there was a rapid increase in plant dry weight in the control, following a roughly sigmoidal growth pattern. Nitrogen increased growth in the control and early grazing treatments, but had no discernible effect on the late grazed treatment. On the early/late grazed treatment, nitrogen application had no effect, but rather promoted weed growth where grazing had removed leaf cover. The weeds present included chickweed (*Stellaria media*), rye grass (*Lolium sp.*), and barley grass (*Hordeum sp.*).

Figure 2.4; Change in total dry matter and its components with time
G indicates time of grazing

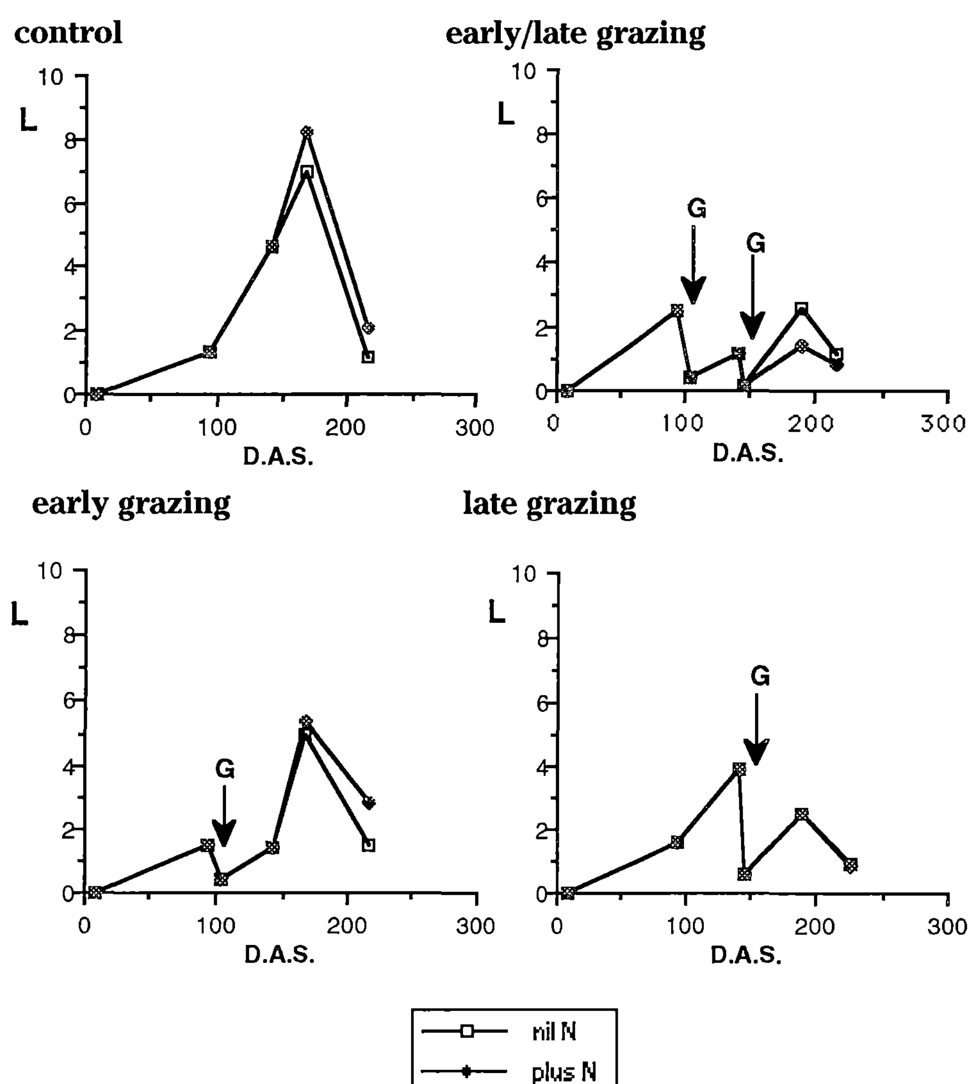


2.2.4 Leaf

Grazing in all cases caused a severe reduction in leaf area index (L) (figure 2.5), and while recovery occurred, especially in the early grazing treatment, the control treatments maintained the highest L throughout the period of growth. Nitrogen application increased the green leaf in the control and early grazing treatments, and prolonged its duration. The early grazed treatments reached maximum L at about the same time as the control treatments. Nitrogen had no effect on leaf area in the late grazing treatment, and depressed L in the early/late treatment. The reduction in L in the early/late treatment due to added N may have been caused by weed growth which, encouraged by nitrogen application, competed with the barley crop for light and moisture.

Green leaf reached a maximum at about the time of ear emergence and then declined rapidly up to the time of maximum dry matter in November, when the last dry weight samples were taken prior to harvest.

Figure 2.5 The effects of grazing and nitrogen on leaf area index (L) over time. G = time of grazing.

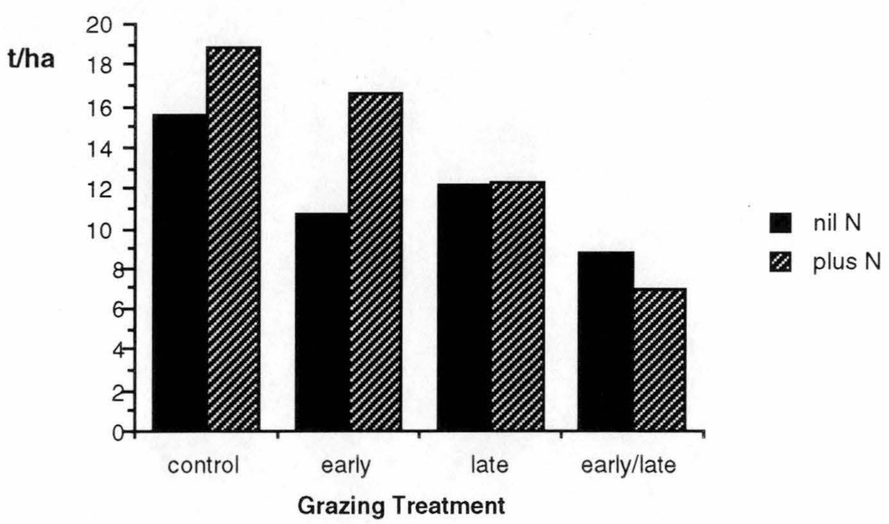


Anthesis was observed in the control plots on October 22nd which was 180 days after sowing. Grazing delayed anthesis, the delay being longer with late or double grazing. Anthesis occurred in the early grazed treatment 185 days after sowing and finally in the early/late treatment at 195 days after sowing.

2.2.5 Maximum Dry Matter

Maximum dry matter was reached at about the dough stage of grain development, corresponding to the last points in figure 2.4. Although there was a wide variation between individual trial plots causing the results to not be statistically significant, the overall trends are obvious (figure 2.6) and were similar to those for grain yield (figure 2.7). The overall trend was for decreased maximum dry matter with increased grazing. For the control and early grazing treatments nitrogen increased maximum dry matter. It had little effect following the late grazing, and may have decreased maximum dry matter with early/late grazing, probably due to the promotion of weed competition.

Figure 2.6; Effect of Grazing on maximum dry matter (t/ha) of all the grazing treatments and control, for both 0 and 50 kg N/ha

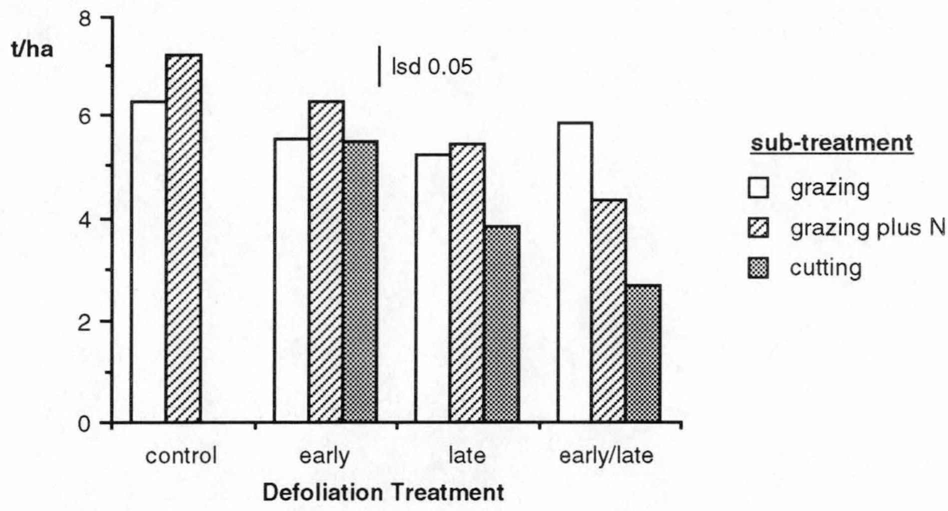


2.2.6 Grain Yield

Grain yield was decreased with increased grazing intensity, from being highest with the no grazing control, to the lowest with the twice grazed early/late grazing treatment (figure 2.7).

The effect of nitrogen application was largest in the control and then declined with increased grazing intensity to a negative effect in the early/late treatment. The negative effect of nitrogen application on the early/late grazing treatment was probably related to the lower L on the nitrogen treatment than the nil nitrogen treatment (see section 2.2.4), a function of increased weed competition. The lower L would have had the effect of reducing photoassimilate available for grain fill.

Figure 2.7; The effect of defoliation on grain yields (t/ha). Bar indicating LSD 0.05 is for sub-treatments.



The reduction in yields due to cutting on the late defoliation treatment, compared to grazing, corresponds to the removal of more forage (fig.2.3). As a result there was a lower L and hence less assimilate for grain fill. This reduction of yield could also have been due to the removal of more shoot apices on the single late cutting, as cutting height was lower than grazing height (fig. 2.2).

If, however, shoot apex removal had been the major factor then the late cutting should have had a lower grain yield than the early/late cutting due to more of the shoot apices being removed. The early/late cutting had a lower L than late cutting over the growing period and it is this low L which was likely to be the major cause of the lowered grain yield.

2.2.7 Straw Length and Harvest Index

Grazing reduced plant height from that of the control (fig. 2.8), and although there was little difference in height between each of the grazing treatments the trend was for a decrease in height with increased grazing intensity. Although there was little difference in plant height between sub-treatments (nil N grazing, grazing plus N, and cutting) at each treatment level, the trend was for N application to increase plant height. The greater plant height after cutting in the early treatment, may have been due to greater residual L remaining after defoliation and hence more assimilate available when rapid stem elongation began. With the late defoliation treatments the reduced amount of assimilate would have been diverted to grain production rather than straw growth.

Harvest index was increased in all cases by defoliation (fig. 2.9), but the trends were inconsistent. The increase was due to a reduction in stem growth following grazing, leading to the reduction in stem dry weight being proportionally larger than that in grain yield.

Although grain yields were similar for the nil N control and the early grazing plus N (fig. 2.7), straw height was reduced and harvest index was increased (fig. 2.9). Available assimilate would have been lower during the period of rapid stem growth, due to reduced L following grazing (fig.2.5), and this reduction in assimilate for stem growth would have resulted in a reduction in straw height. However by the time of anthesis and grain fill L had recovered to a level sufficient to intercept most radiation, consequently yields were similar to those of the control, whilst harvest index was increased. In times of crop stress when reserves stored in the stem can be important for grain fill, the reduction in straw may cause a reduction in grain yield.

Figure 2.8; Effect of defoliation treatment on straw length at harvest. Bars indicating LSD 0.05 for (a) defoliation treatment and (b) sub-treatment.

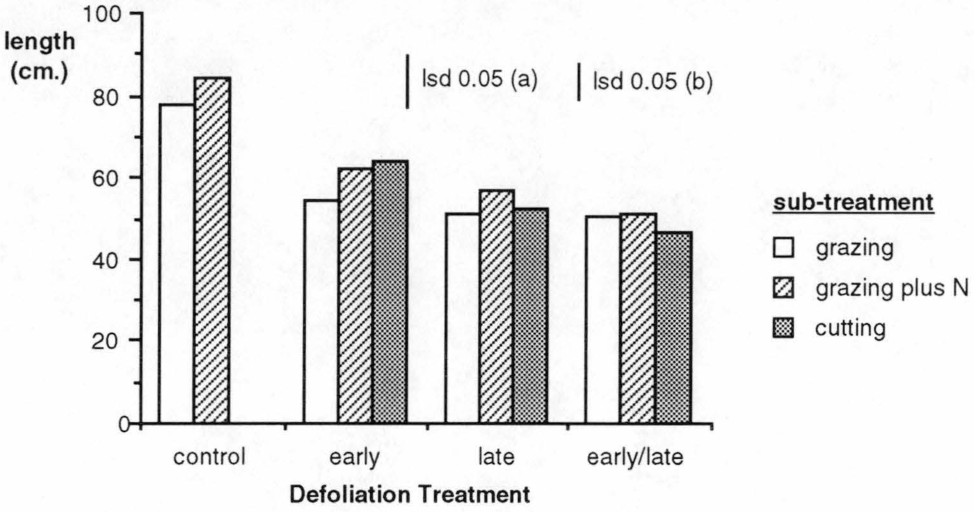
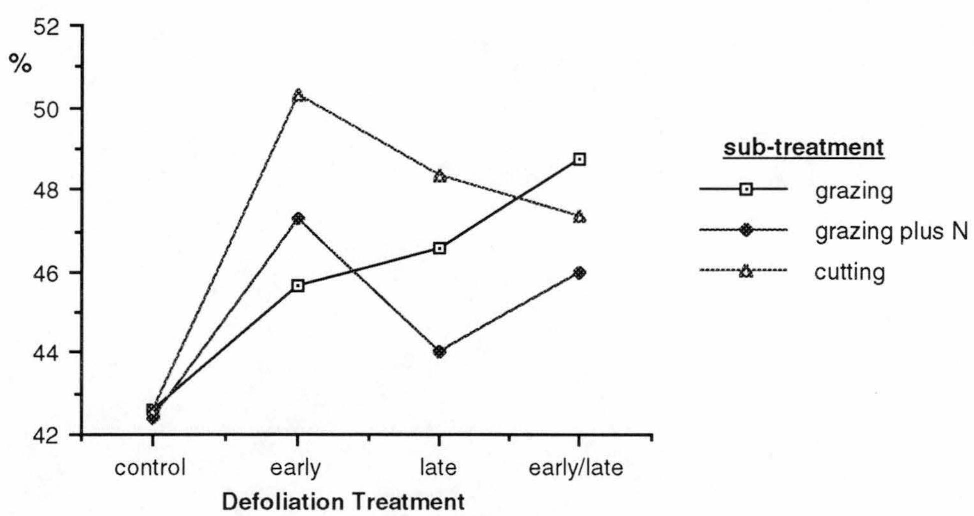


Figure 2.9: Change in Harvest Index (grain as a % of total plant dry weight) with increased grazing intensity.

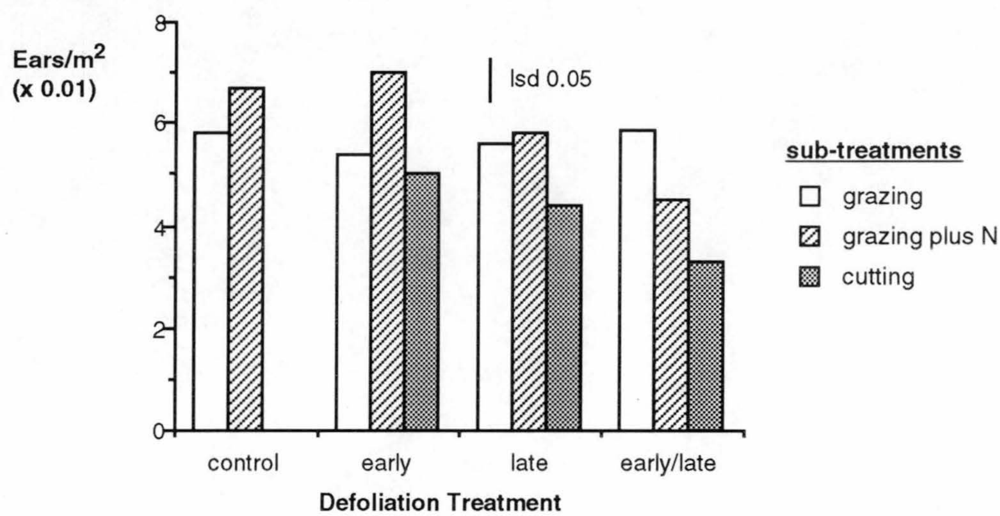


Lodging was observed on the control plots from early December, caused by wind and rain, and increased up to the time of harvest in early January. The worst effects were observed on the plus N control which had the longest straw. It is possible therefore that the reduction in straw length due to grazing would be an advantage in years where adverse weather could cause bad lodging.

2.2.8 Components of Yield

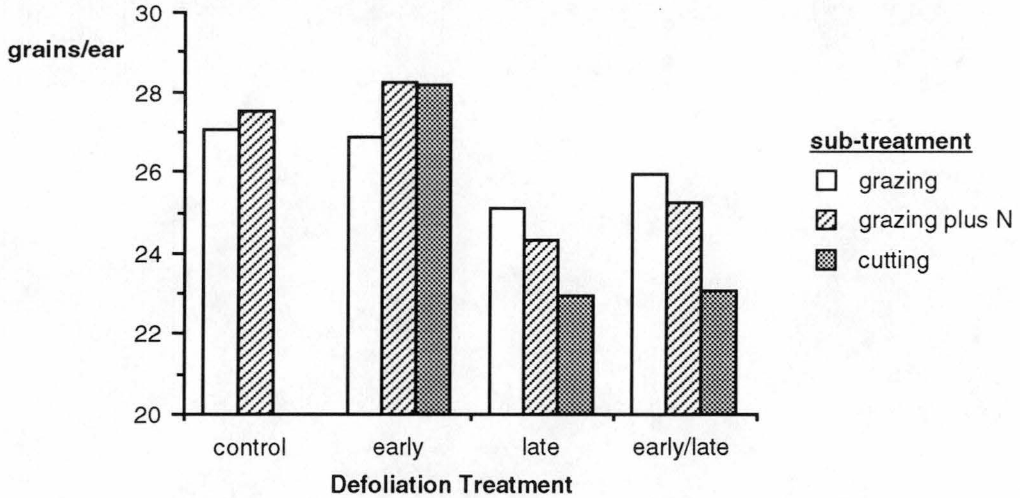
Grazing had little effect on the number of ears per m^2 unless nitrogen was added (fig. 2.10). Nitrogen boosted ear numbers with nil or early grazing, had little effect on late grazing and may have reduced ear number on the early/late grazing treatment. With both the treatments involving late defoliation, cutting decreased ear number below that for grazing, probably reflecting the removal of growing tips and also the lower tiller survival due to less available assimilate.

Figure 2.10; Effect of defoliation on ear number per square metre. Bar indicating lsd 0.05 is for sub-treatments.



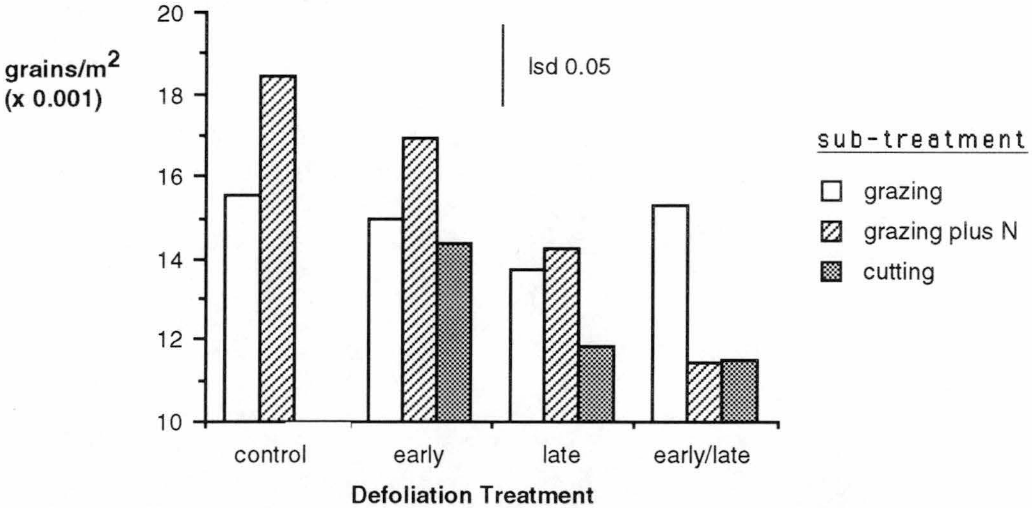
The trend for a decrease in grain number per ear with treatments involving late grazing (fig. 2.11), was due to reduced L at the time of rapid stem elongation leading to fewer spikelets per ear. With the treatments involving late grazing the pattern was for added N to decrease grain number as did the cutting treatments. As N did not appear to affect L on the late grazing treatment (fig. 2.5), the reduction in grains per ear due to added N would be due to the increase in ear number (fig. 2.10) without a corresponding increase in available assimilate to fill grain sites. The reduction in grains per ear due to added N in the early/late treatment is however likely to be due to the apparent reduction in L following N application and hence less available assimilate, which is probably a function of increased weed competition.

Figure 2.11; The effect of defoliation on grain number per ear.



Numbers of ears and grains/ear combine to give number of grains/m^2 (fig. 2.12) where the trend was for nitrogen to cause an increase for all treatments, except the early/late grazing. Grazing, without N application, did not appear to cause a substantial reduction, whereas when N was applied grain numbers were progressively reduced with more intense grazing.

Figure 2.12; Effect of defoliation on grain number per square metre. Bar indicating LSD 0.05 is for sub-treatment.



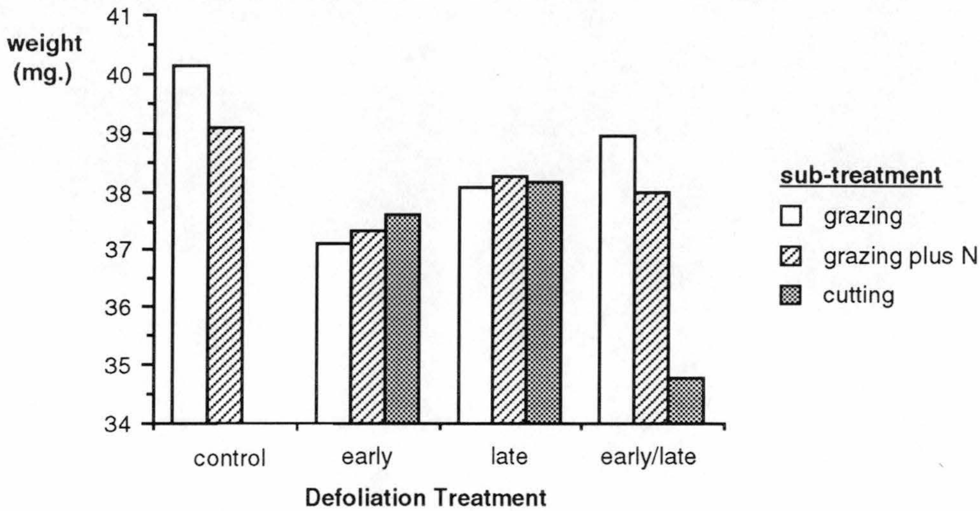
Nitrogen increased grain number on the control, early grazing and late grazing treatments mainly by increasing ear number. This indicates that nitrogen helped in tiller survival, a greater number surviving to produce ears than with nil N or cutting. Grain number for the late grazing treatments was decreased below that of the early grazing at least where N was applied but ear number was not, suggesting that while late grazing did not affect tiller number any more than early grazing it had a greater effect in reducing spikelet formation. This would be due to late grazing having removed mainstem and early tillers from some plants resulting in dependence on later formed, weaker (i.e. fewer spikelets) tillers, as observed by Abdul-Rahman et al (1987).

With both treatments involving late defoliation, cutting reduced grains/m^2 below that of grazing, due both to the removal of shoot apices resulting in fewer ears and the greater reduction of L.

Individual grain weight was decreased most by early grazing (fig. 2.13), probably because grain and ear number were not affected, but due to shorter leaf area duration assimilate to fill grains never reached the level of the control.

The trend for a decrease in individual grain weight due to defoliation is again evident in a comparison of cutting and grazing. In the early/late treatment cutting caused a large reduction in individual grain weight over that of grazing, presumably due to the low L throughout the growth of the crop.

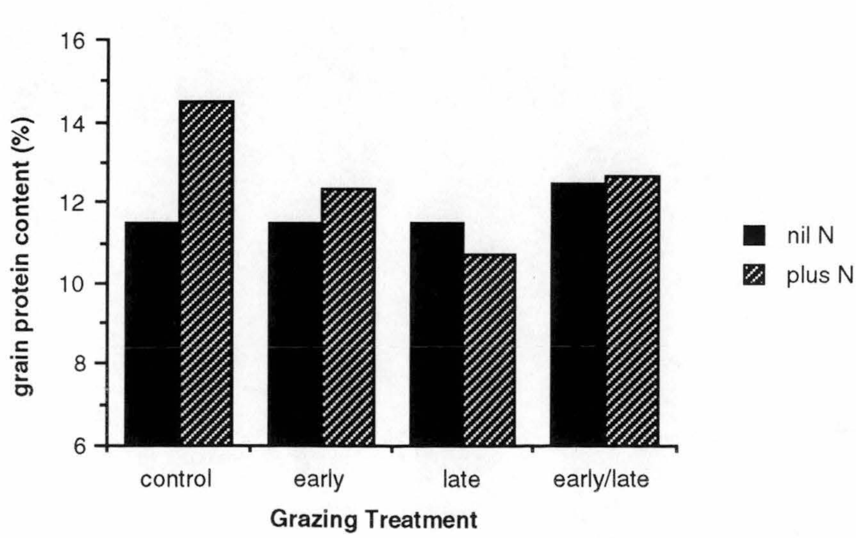
Figure 2.13; Effect of defoliation on individual grain weight (mg).



2.2.9 Grain Protein

Grain protein content was high (fig. 2.14), with little difference between nil N grazing treatments. N application improved protein content on the control and early grazing. The effects of grazing and N application on grain protein will be discussed more fully in chapter three.

Figure 2.14 Effect of grazing on grain protein content.



2.2.10 Conclusion

When used as a dual-purpose crop, the grazing of Ulandra did not reduce grain yield if grazed early allowing L time to recover. The application of nitrogen on the early grazing treatment fully compensated for the effects of grazing, although there was also a benefit from N on the ungrazed control. As grazing was increased in intensity (i.e. grazed late or grazed twice) there was a trend towards a greater reduction in grain yield, although the early/late treatment without N performed surprisingly well, considering the limited leaf area and amount of forage removed. Nitrogen did not compensate for this and in the case of the early/late treatment it reduced yield.

Forage yield was greatest with the single late grazing, however the cattle tended to waste some of the available forage. If grain yield is important then grazing should cease early to allow L time for recovery. Abdul-Rahman (1988) presented some evidence to show that residual L following grazing was important in determining the crops recovery. This appears to have been confirmed by the single late grazing where although total forage removed was more than the total removed by both grazings of the early/late grazing, there was a greater L remaining following the late grazing resulting in a higher final grain yield.

The opening up of the leaf canopy and the application of nitrogen promoted weed growth on the early/late grazing treatment. As a result of weed competition crop growth and final grain yield were reduced. Better weed control may overcome this problem.

Grazing reduced straw length, which contributed to an increase in harvest index, as well as preventing lodging. Whilst lodging occurred in the control plots, it was not severe enough to reduce grain yields below those of the grazed treatment, however in a season where crops were more susceptible to lodging, the effects may be more severe.

Cutting of the early grazed treatments successfully predicted forage and grain yields as well as the effects on the yield components, however it overestimated forage removed and the reduction in grain yield on both late grazing and early/late grazing. The difference was largely due to the amount of leaf remaining after defoliation, as the cattle did not remove all the leaf above defoliation height, whereas cutting did.

Removal of the more advanced shoot apices in the single late grazing, leaving grain yield to be carried by weaker secondary tillers, and poor recovery in L appear to be critical factors in reducing grain yield following late grazing. If there was more time for recovery, yield potential may be improved. It may be possible to achieve this through an earlier sowing date.

CHAPTER THREE

SOWING TIME AND ITS EFFECT ON FORAGE AND GRAIN YIELD OF A DUAL-PURPOSE WINTER BARLEY

The previous season's experiment demonstrated that it was possible to graze barley without significant loss of grain yield. Loss of grain yield increased if grazing was delayed or grazing pressure was increased (i.e. grazed twice). However to develop a suitable management program for grazing barley, information would be needed on the effect of a range of sowing times. Therefore it was decided to conduct a similar experiment to that of the previous season, but varying the sowing time from early to mid autumn.

3.1 Materials and Methods

3.1.1 Experimental Design

The experiment used three sowing times which were; March 23rd, April 10th, and April 28th. Full emergence in all sowings was 8 to 9 days after sowing.

Angus yearling heifers were used to graze the plots (plate 3.1). As with the previous experiment for each sowing there were three replicates each with four grazing treatments, which were;

i) control ; no grazing
ii) early grazing
iii) late grazing
iv) early/late grazing ; a combination of (ii) and (iii).

The barley cultivar Ulandra, was once again used, being sown at a rate of 120 kg/ha. The fertilizer 14-16-11 (N:P:K) was drilled with the barley seed at a rate of 250 kg/ha. An extra replicate of the 2nd sowing was sown. Following the completion of the late grazing all plots within each replicate were split, with nitrogen (in the form of sulphate of ammonia) being applied to half the plot at the rate of 50 kg N/ha.

A site was again selected at Thirlstane on the North-West coast of Tasmania, on krasnozem soil (plates 4.1 and 4.2). The site had been in pasture until 1987 when it was sown to poppies followed by an autumn sown crop of onions in 1988. The onions were harvested in January 1989 and the site was immediately prepared for the barley crop.

Following emergence the position of the shoot apex in relation to grazing and cutting height was monitored using individual plant samples.

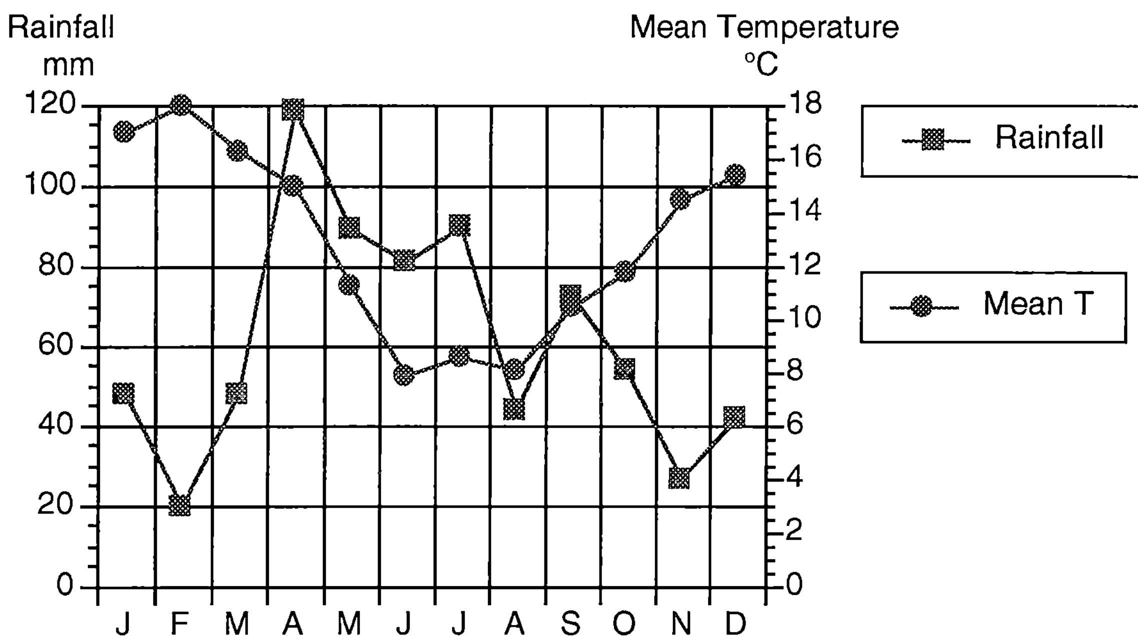
3.1.2 Cutting

As in the previous season a cutting trial was run concurrently with the grazing to assess whether it is possible to artificially simulate grazing using this method, using a 1m^2 sub-plot as previously.

3.1.3 Climate

Rainfall and mean monthly temperatures for 1989 are shown in figure 3.1. The weather pattern was similar to the previous year, but heavy rain in April meant that soils were wet from then until late Spring. This caused difficulties with the second sowing making the ground very soft, hence deep wheelmarks were left in some plots. For this reason an extra replicate was sown. Heavy rain also delayed the completion of the early grazing of the first sowing. Wet weather caused several delays of and interruptions to grazing during the course of the experiment.

Figure 3.1; Monthly rainfall and mean temperature for 1989



3.1.4 Waterlogging

Waterlogging started to become apparent in some plots by early July. There was a noticeable yellowing of the first sowing around this time (plates 5.1 and 5.2). Pugging damage due to the effects of livestock on soft soil was also noticed on some of the grazed plots (plate 3.2). The third sowing generally appeared to escape the worst of these effects.

Waterlogging occurred mainly as a result of the experimental site, which lay at the foot of a hill and collected runoff from rainfall. Plots furthest from the foot of the hill escaped the effects of waterlogging.

3.1.5 Other measures

An intended application of herbicide in September was not carried out due to the wet condition of some plots. Benlate® was applied to all plots on 27/10, following the detection of leaf scald in some plots. The insecticide Le-Mat® was applied at the same time as the Benlate® to control red-legged earthmite. Mesurol® was applied to all plots on 11/11 to prevent excessive bird damage. All chemicals were applied at recommended rates.

1m^2 samples from each plot were hand-harvested as they became ready in late December and early January. Grain yield, N content, yield components, straw length and harvest index were determined as in the previous year.

3.1.4. Statistical Analysis

A split/split plot analysis of variance was carried out on forage yield, grain yield, yield components, straw length and harvest index using the method proposed by Chakraverti et al (1936). The analysis for grain yield is shown in appendix B. Least significant differences (lsd's) are indicated on figures in this chapter only where the result was statistically significant.

The regression lines in the section on waterlogging were calculated using the StatView SE + Graphics™ program for the Apple Macintosh computer.

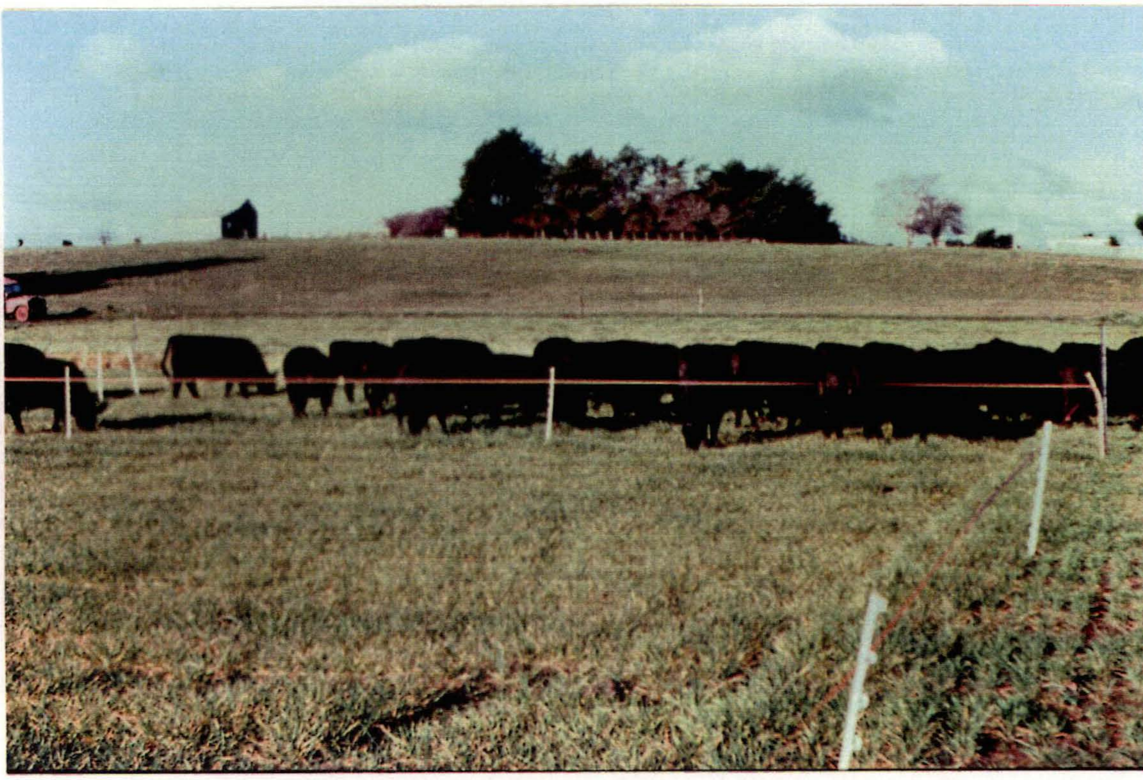


Plate 3.1 Early grazing of the late April sowing on 24th August 1989 using Angus yearling heifers. Runoff from the slope in the background caused waterlogging problems on some plots

Plate 3.2 Hoof damage caused by grazing cattle on soil which had been softened by rain.

Plate 4.1 A view of the 1989/90 trial on 21/4/89 just after the emergence of the second sowing.

Plate 4.2 A closer view of the second sowing on the same day as plate 4.1.

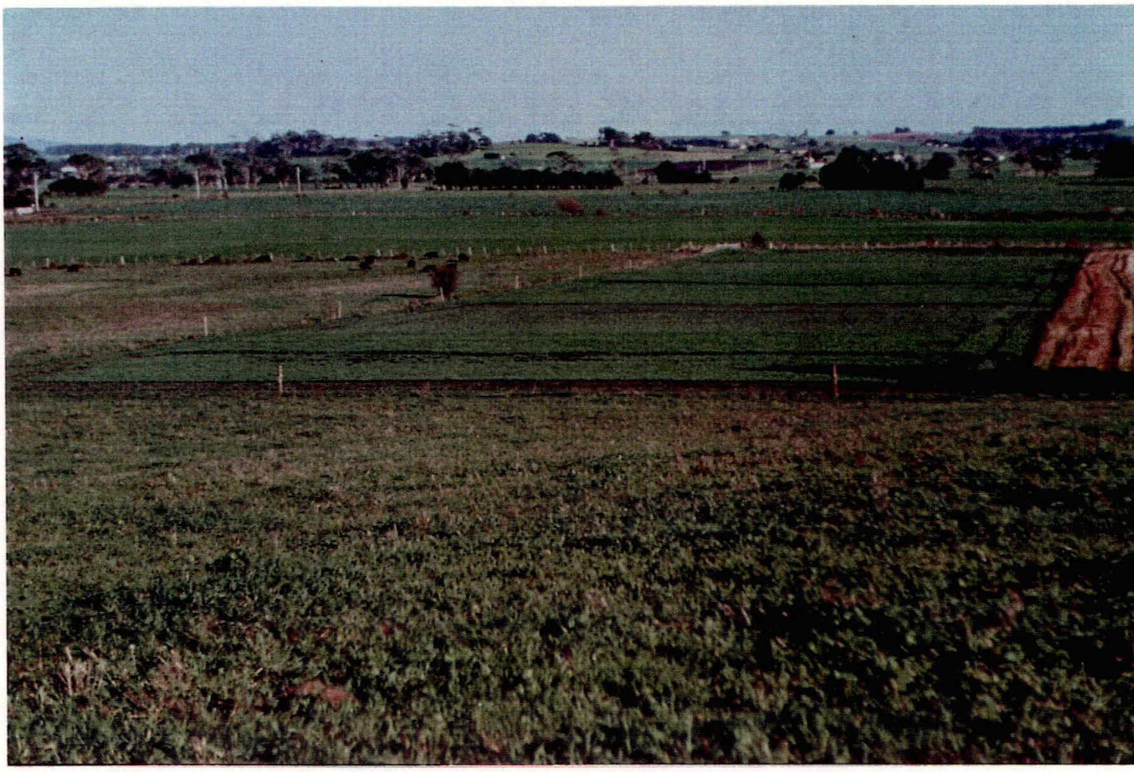
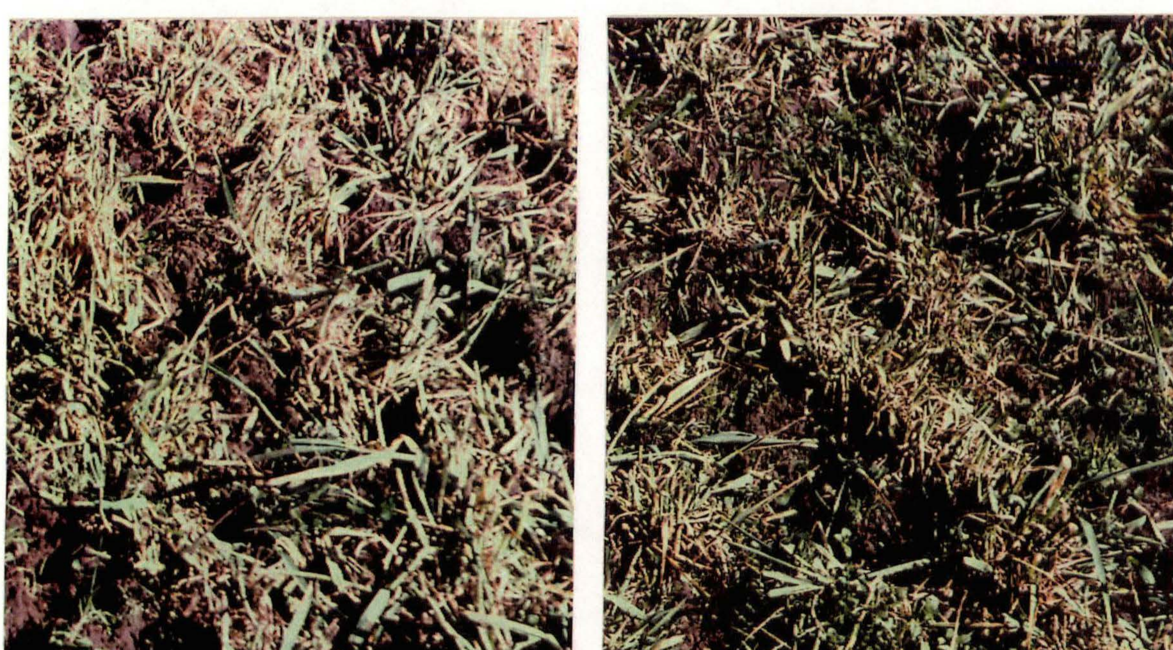


Plate 5.1 A view of the trial in late June just prior to the first grazing of the first sowing.

Plate 5.2 In comparison to the view in plate 5.1 there was noticeable yellowing in the trial by mid July as the result of waterlogging.

Plate 6.1 On the late grazing of the second sowing cutting (inside the stakes) was to a lower height than grazing (outside the line) resulting in more forage being removed by cutting.



(a) (b)

Plate 6.2 Following the second defoliation a greater length of stem remained on the single late grazing treatment (a) than on the early/late grazing treatment (b).

3.2 Results and Discussion

3.2.1 Forage Removed

Forage removed by grazing and cutting was assessed as in the previous season. The early grazing for the first and third sowings was carried out as soon as it was judged that a sufficient amount of forage was available. Whilst this assessment was carried out visually it meant that the first grazing occurred just after full ground cover and a total plant biomass between 1 and 2 tonne/ha were achieved. At this stage the growing points were still below the soil surface (figure 3.3, page 38), which in the first sowing was between 62 and 73 days after sowing. Although there was adequate forage to graze the second sowing earlier than occurred, grazing was delayed due to wet weather which made the ground soft and susceptible to pugging damage from the grazing animals. As a result the second sowing was grazed between 66 and 71 days after sowing. Grazing dates for all sowings are shown in table 3.1 below.

The third (late April) sowing did not have sufficient forage for grazing until 116 days after sowing which was in late August. The slower growth rate was due to the low winter temperatures and wet weather which followed seedling emergence.

Table 3.1; Grazing Dates for each Sowing and Grazing.

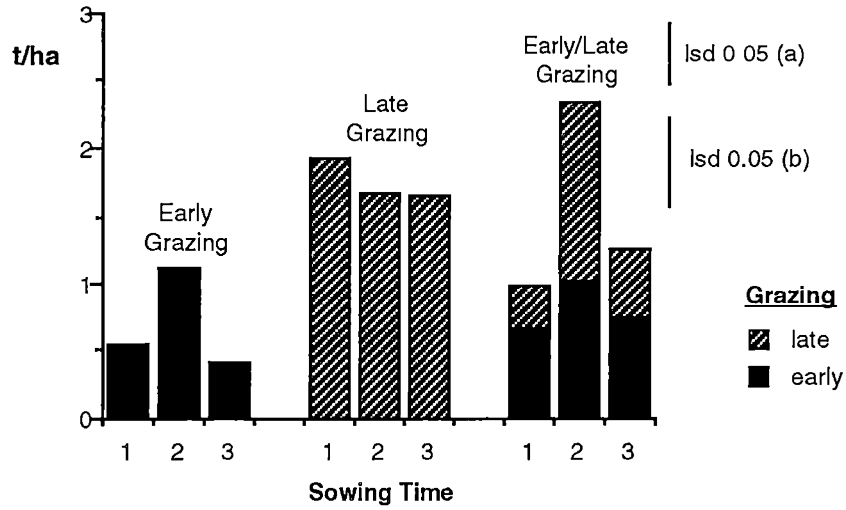
Sowing	Grazing	Grazing Dates
first	first	24/May to 4/June
	second	12/August to 14/August
second	first	16/June to 19/June
	second	24/August to 28/August
third	first	22/August to 24/August
	second	15/September to 16/September

The late grazing was carried out just prior to when it was estimated that the shoot apex of the plants would have reached grazing height and therefore been subject to the danger of removal. All three sowings reached this stage at about the same number of days after sowing. Late grazing of the first sowing was carried out between 142 and 144 days after sowing, of the second sowing between 136 and 140 days after sowing, and the third sowing at 140 and 141 days after sowing. This meant grazing in mid-August, late August, and mid-September respectively. Thus forage was available from early winter (late June) through to early spring (mid-September), giving a range of options covering most times of feed shortage that a farmer may have.

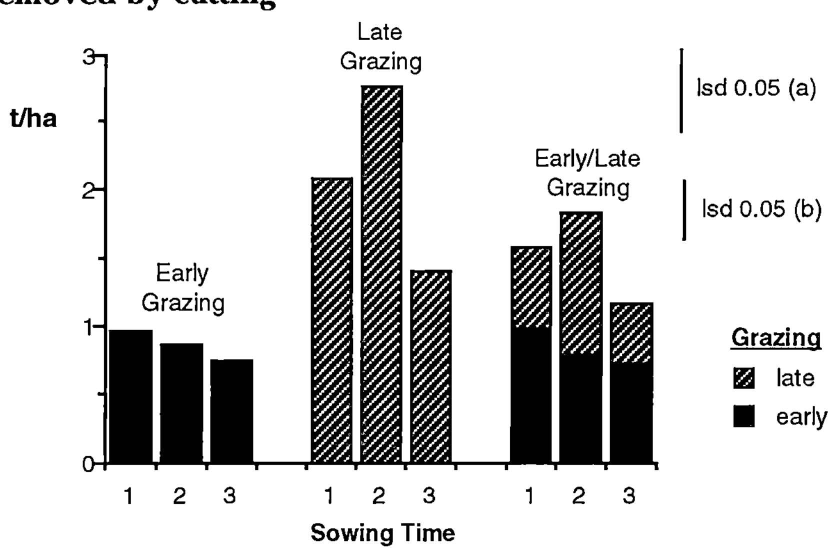
The grazing in the early/late treatments was timed to coincide with the single early and late grazings for each sowing treatment. Figure 3.2(i) shows the amount of forage actually removed by the cattle for each grazing treatment, and figure 3.2(ii) shows forage removed by cutting.

Figure 3.2; A comparison of forage removed between different sowing treatments. Bars indicating lsd's (0.05) are (a) between sowing times, and (b) between defoliation treatments.

(i) forage removed by grazing cattle



(ii) forage removed by cutting



Forage removed by grazing was similar between the sowing times for each of the defoliation treatments (early, late, and early/late) (fig. 3.2(i)), the exception being with the second sowing where due to wet weather delaying the early grazing, more forage was removed with the early and early/late treatments than occurred with the other sowings. This general trend also occurred with cutting (fig. 3.2(ii)).

In a cutting experiment sown at Cressy Research Station near Launceston in late March, using several different barley cultivars (see appendix C) Vertigan and Young achieved similar forage yields to those in this experiment. However they made a third (early spring) defoliation which resulted in a higher overall forage yield for the season.

Despite defoliation heights being similar (fig. 3.3), the amounts of forage removed differed between sowing times. More forage was removed by cutting than grazing, at least on the first and third sowings when grazed early and on the second sowing when grazed late (plate 6.1). The single late grazing of the first and third sowings yielded more forage than double grazing, whereas in the second sowing double grazing yielded more forage. The second sowing showed better recovery in plant weight following the early grazing than either the first or third sowing (fig.3.7, page 43).

3.2.2 Development of the shoot apices

The height of the shoot apex in relation to time from sowing and defoliation height is shown in figure 3.3. It is possible that grazing or cutting may have removed some of the more advanced shoot apices, as the values for grazing, cutting, and shoot apex heights are averages taken over the plots, but in general removal of the shoot apices appears to have been avoided.

The first grazing slowed the rate of elongation of the shoot apex so that at the time of the second grazing it was lower than in ungrazed plots (fig. 3.3). However at the second defoliation the cattle tended to eat the previously grazed plots to a lower height than the control plots (plates 6.2 a and b), therefore generally grazing above the height of the shoot apex in both cases. Although cutting height at the late defoliation tended to be lower than grazing height, it remained above the height of the shoot apices.

The shoot apex took more calendar days to emerge above the soil surface with later sowing due to lower temperatures at this time. When plotted against thermal time (accumulated day degrees above 0°C) the time of emergence above the soil surface and rate of elongation of the shoot apex are virtually the same for all three sowings (figure 3.4).

From table 3.2 it can be seen that the stage of development at which the first grazing took place for each sowing shows the effect of lower temperature. With the second and third sowings early grazing took place at an earlier stage of apex development than on the first sowing. These stages outlined previously in section 1.7, are as used by Kirby and Appleyard (1984):

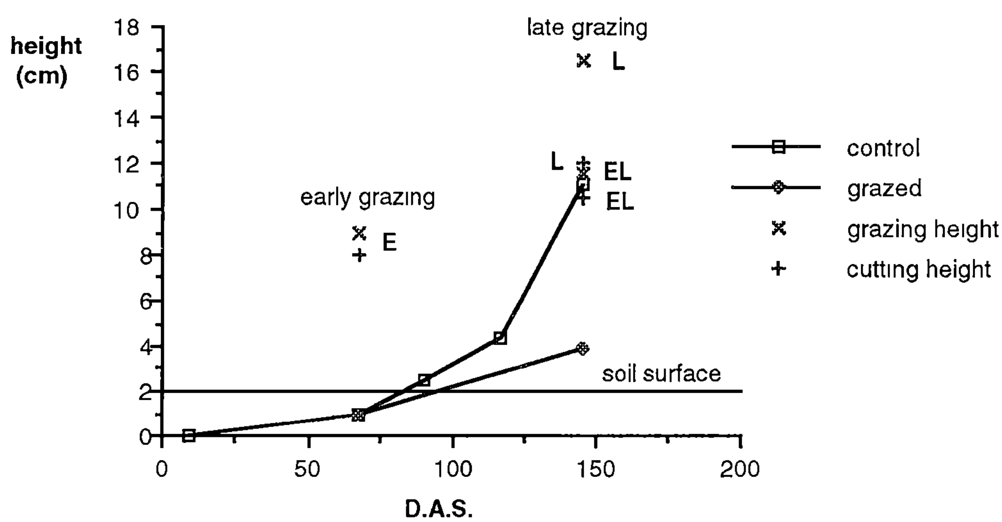
1) vegetative
2) double ridge
3) triple mound
4) glume primordium
5) lemma primordium
6) stamen primordium
7) awn primordium

Table 3.2; Stage of development of shoot apex of each treatment prior to grazing.

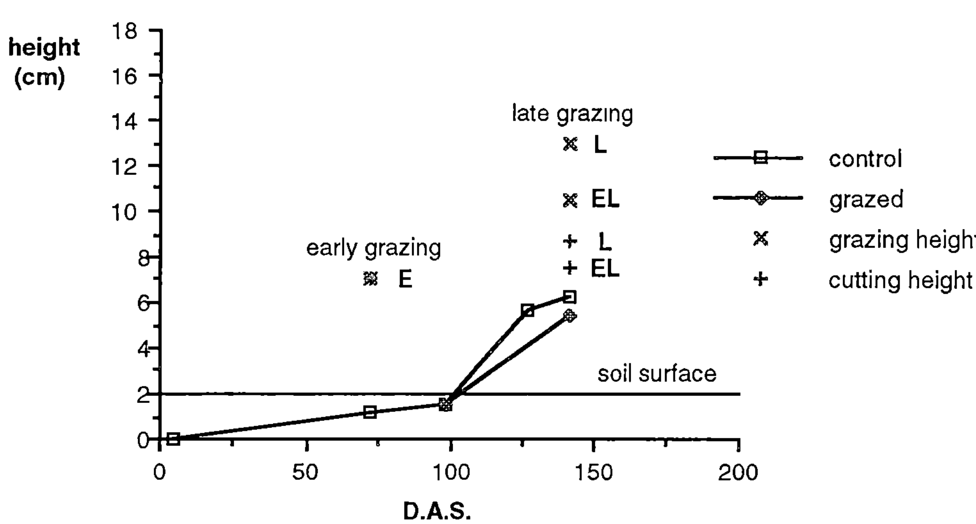
Sowing	early	late	early/late
first	7	7	6 - 7
second	2 - 3	7	7
third	5	7	7

Figure 3.3; A comparison of cutting and grazing heights with height of mainstem apex above the base of the crown, in relation to days after sowing (D.A.S.). Defoliation heights for both grazing (x) and cutting (+) are shown for the early grazing (1st defol.) and the late grazing (2nd. defol.) where (E) is the height of the early grazing, (L) is the height of the single late grazing, and (EL) the height of the late grazing of the early/late treatment.

(i) First Sowing



(ii) Second Sowing



(iii) Third Sowing

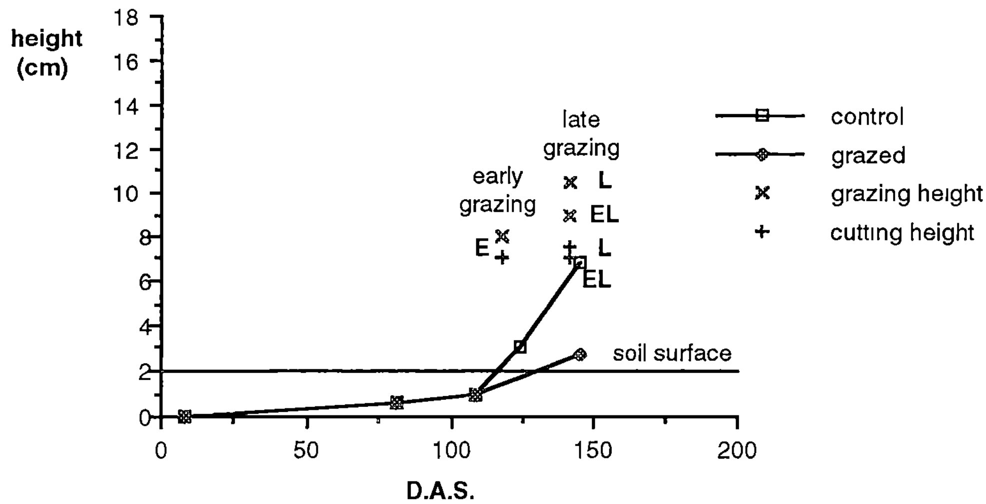
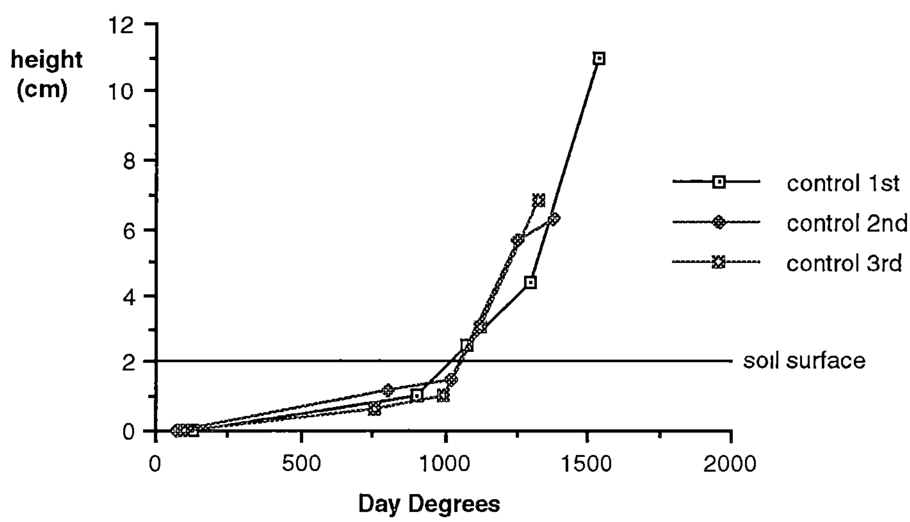


Figure 3.4; Height of Shoot Apex of the control treatment in thermal time (day degrees above 0°C) for all three sowings



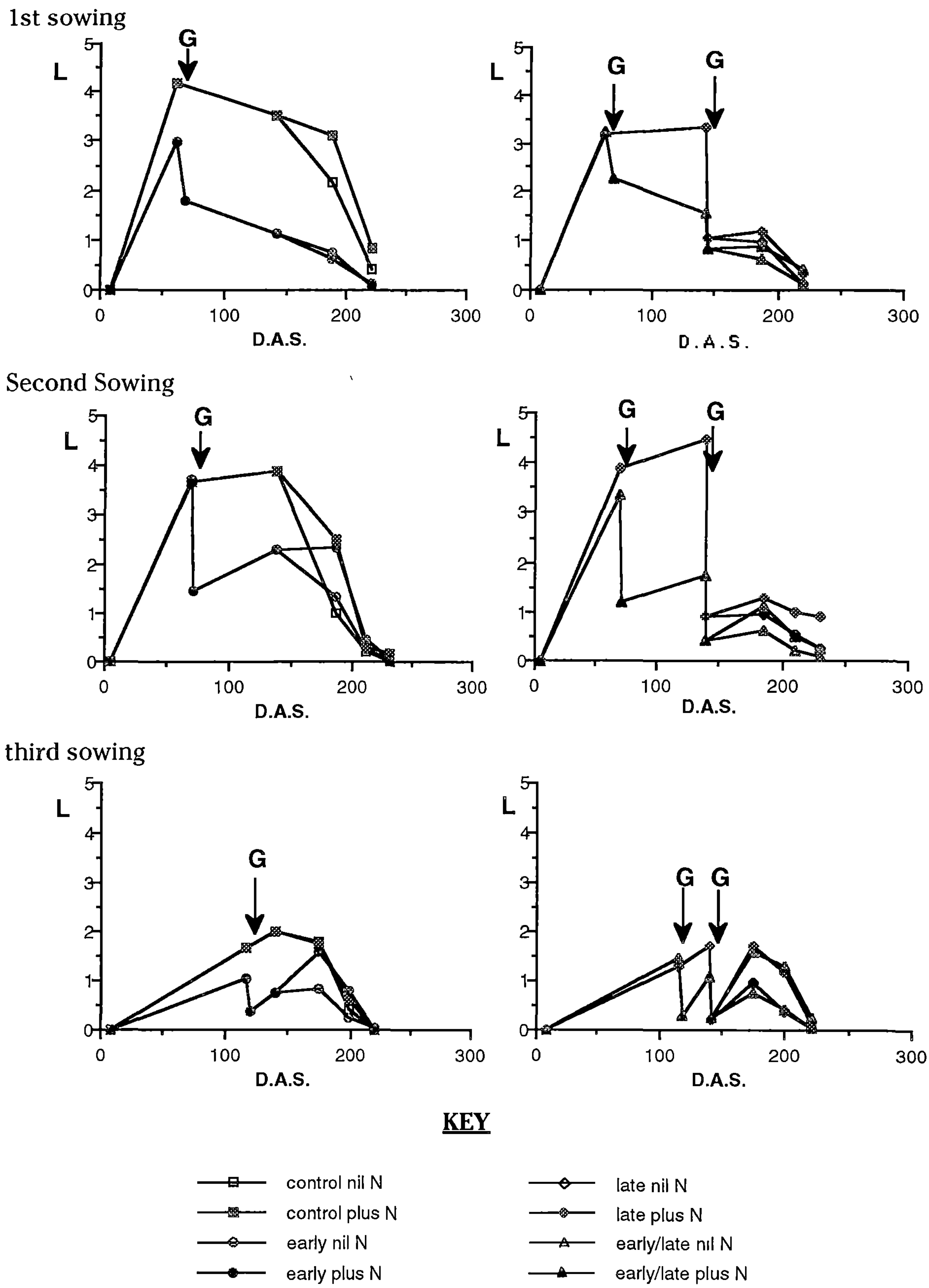
As well as slowing the rate of elongation of the shoot apex grazing also reduced the length of the ear, as shown below (table 3.3), measured at the time of the second grazing.

Table 3.3 Effect of grazing on length of developing ear

The slowing in the rate of both stem and shoot apex elongation are presumably due to a reduction in available assimilate caused by the reduction in leaf area L (figure 3.5).

	Ear Length (cm)		
	1st Sowing	2nd Sowing	3rd Sowing
ungrazed	0.62	0.58	0.74
grazed	0.29	0.48	0.49

Figure 3.5 The effects of grazing and nitrogen on L over time.
G = time of grazing



3.2.3 Leaf

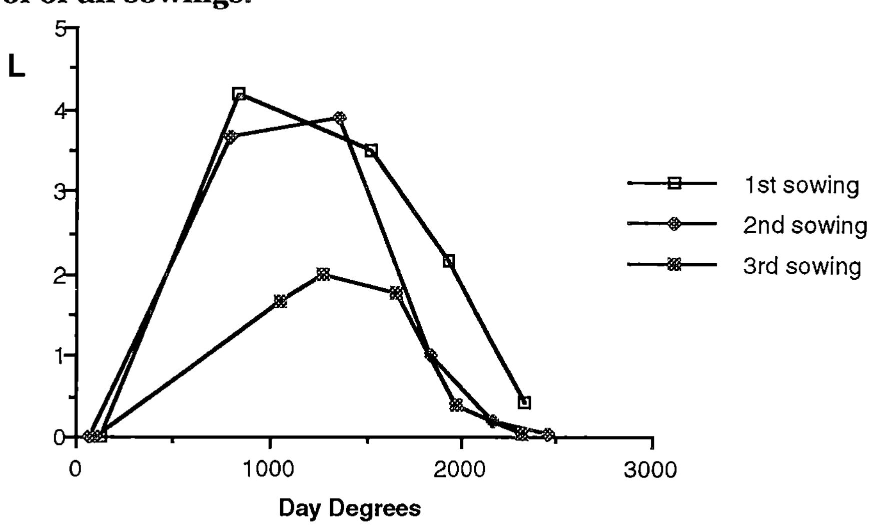
Leaf area indices (L), shown in figure 3.5, were low for all treatments regardless of sowing, never reaching a level of 6 which is needed for near full light interception. With the first sowing there was no increase in L after any of the grazing treatments, and it appears that L declined in all treatments including the control following the time of the first grazing. However there may have been new leaves growing which were not large enough to replace old ones removed or senescing, as L remained for a long time after the first grazing. The addition of nitrogen following the second grazing increased L on all treatments but only marginally. Unlike the other two sowings L for the late grazed treatment was higher throughout crop growth than L for the early grazing.

With the second sowing there was some recovery in L following the early grazing and in all grazing treatments the addition of nitrogen assisted in leaf recovery. The late grazing treatment maintained its leaf cover up until that time, but the recovery in L of the early grazing treatment gave it a higher L later in the growth of the crop where this would have been important in supplying assimilate for grain fill.

L in the third sowing was low for all grazing treatments and the control, in comparison with earlier sowings or the previous year. Nitrogen had little effect on L of the control, however on all of the grazing treatments its effects were noticeable leading to an almost full recovery in leaf area by 174 days after sowing.

The duration of L was similar for all sowings with leaf death occurring at about the same time after sowing. Duration of L was also similar in thermal time for all sowings (figure 3.6). The very poor rate of leaf growth of the third sowing would appear not to be temperature related, but rather caused by waterlogging.

Figure 3.6; Effect of thermal time (accumulated day degrees above 0°C) on L of the nil N control of all sowings.



3.2.4 Crop Growth

As with L, dry matter production (fig. 3.7) for all treatments was lower than that of the previous year for the same treatment. Trends in dry matter production differed between the three sowings. The first and second sowings had rapid early growth but then slowed in early winter, after which they increased steadily up to maxima in late October and early November respectively. In contrast growth on the third sowing was slow until early spring when dry matter increased rapidly up to a peak in late November. This resulted in the different times of grazing for the different sowings, as the third sowing took longer to produce sufficient forage for grazing.

Patterns in recovery of dry matter following grazing were generally similar on comparable grazing treatments for each sowing. Recovery following early grazing was good for the second and third sowing with dry matter increasing to well above pre-grazing levels, but on the first sowing there was virtually no recovery. With late and early/late grazing for all sowings dry matter recovered to about the pre-grazing level but did not increase much past this. In most cases nitrogen noticeably increased dry matter production.

From early winter there was a large increase in dead matter in the controls of the first and second sowings, indicating either leaf senescence or tiller death, possibly linked to the effects of waterlogging and low light intensity.

There was very little weed in the control treatments. In both the early and early/late treatments weed greatly increased after the time of the second grazing. The increase in weed was not as marked in the single late grazing treatment. In the late grazing treatment nitrogen application appeared to promote weed growth, as in the previous season. Weed growth may have been increased following grazing due to an opening up of the leaf canopy and reduced competition from the barley. The decrease in green leaf coincided with a rise in the amount of dead matter, which was predominantly dead leaf.

Recovery after early grazing was poor in the first sowing. The maximum dry matter reached was similar to that in the early/late grazing, and lower than in the late grazing where more forage had been removed.

With the second sowing, crop dry matter recovered well following the single early grazing. There was little recovery following late grazing for either the single late grazing or the early/late grazing when nitrogen was not applied. Nitrogen increased crop dry matter in all treatments except the early grazing, where the weed population appeared to benefit the most. Grazing had most effect in reducing leaf and only a small effect on the amount of stem. Most stem was removed by the single late grazing. Again stem production was increased by the application of nitrogen. It was also apparent that ear emergence was earlier in the control treatments than in the grazed treatments.

The third sowing gave generally slow growth and leaf area expansion up to the time of grazing, during the period when the effects of waterlogging were the greatest. Recovery afterwards was relatively good, particularly when nitrogen was applied. This mainly reflects better weather conditions as grazing of the third sowing was not until late August-early September. The maximum dry matter reached was less than for the previous sowings, due to the poor early growth. Weed growth accounted for a greater proportion of the total dry matter, for all treatments, than it did in the first two sowings. Once again the ears emerged earlier on the controls than on the grazing treatments.

The effects of grazing on all three sowings can be summarized as follows. There was a good recovery in crop dry weight following the early grazing, except on the first sowing where cold wet conditions during and immediately after grazing were likely to have hampered regrowth. Nitrogen assisted growth but also promoted weed growth especially when ground cover was thin as with the early/late grazing treatment. Forage removal was largely of leaf with little removal of stem except in the single late grazing treatment. This would indicate that with the exception of the late grazing treatment the growing tip was unlikely to have been removed.

Figure3.7 Change in total dry matter with time

3.7.1 First Sowing

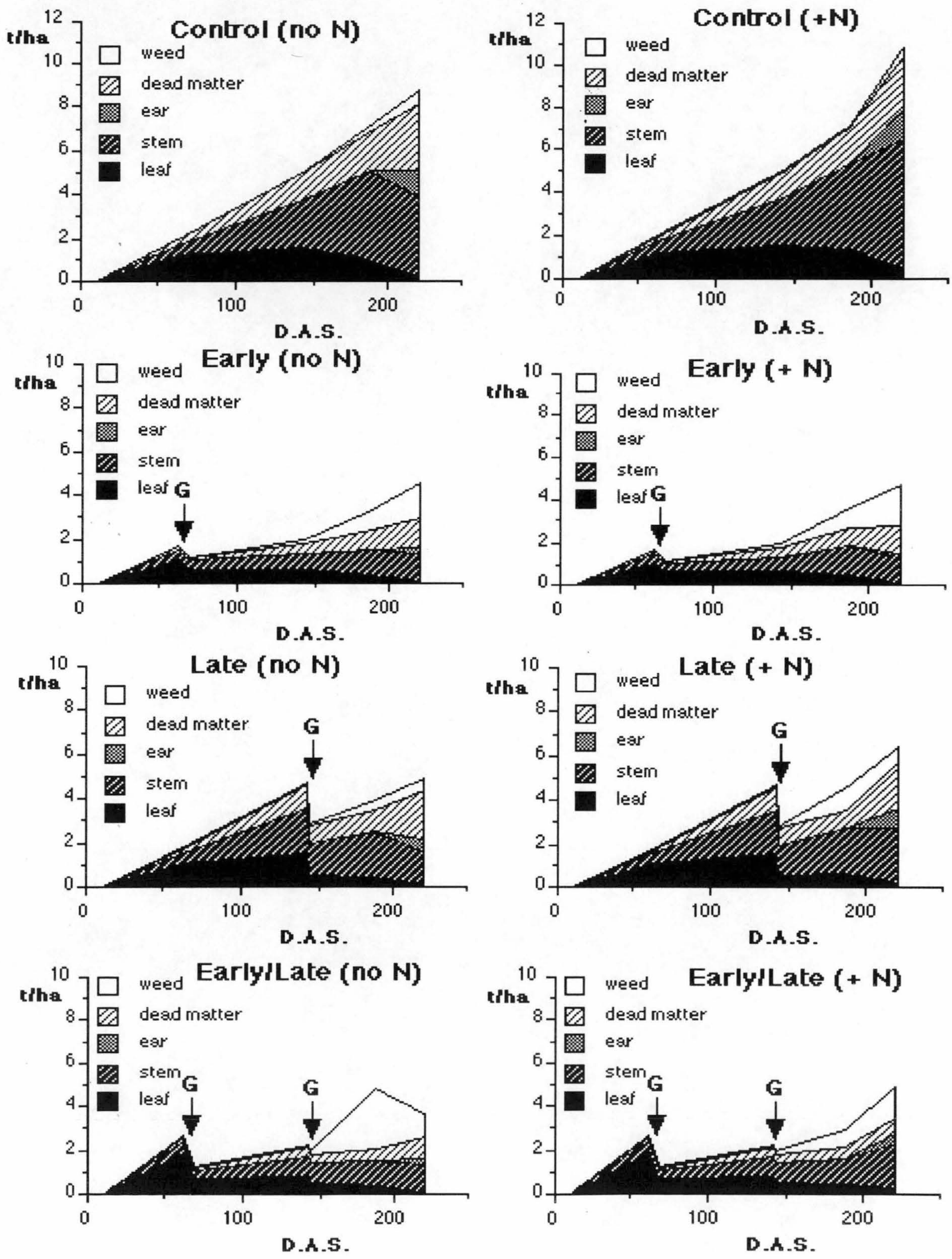


Figure 3.7.2 Second Sowing

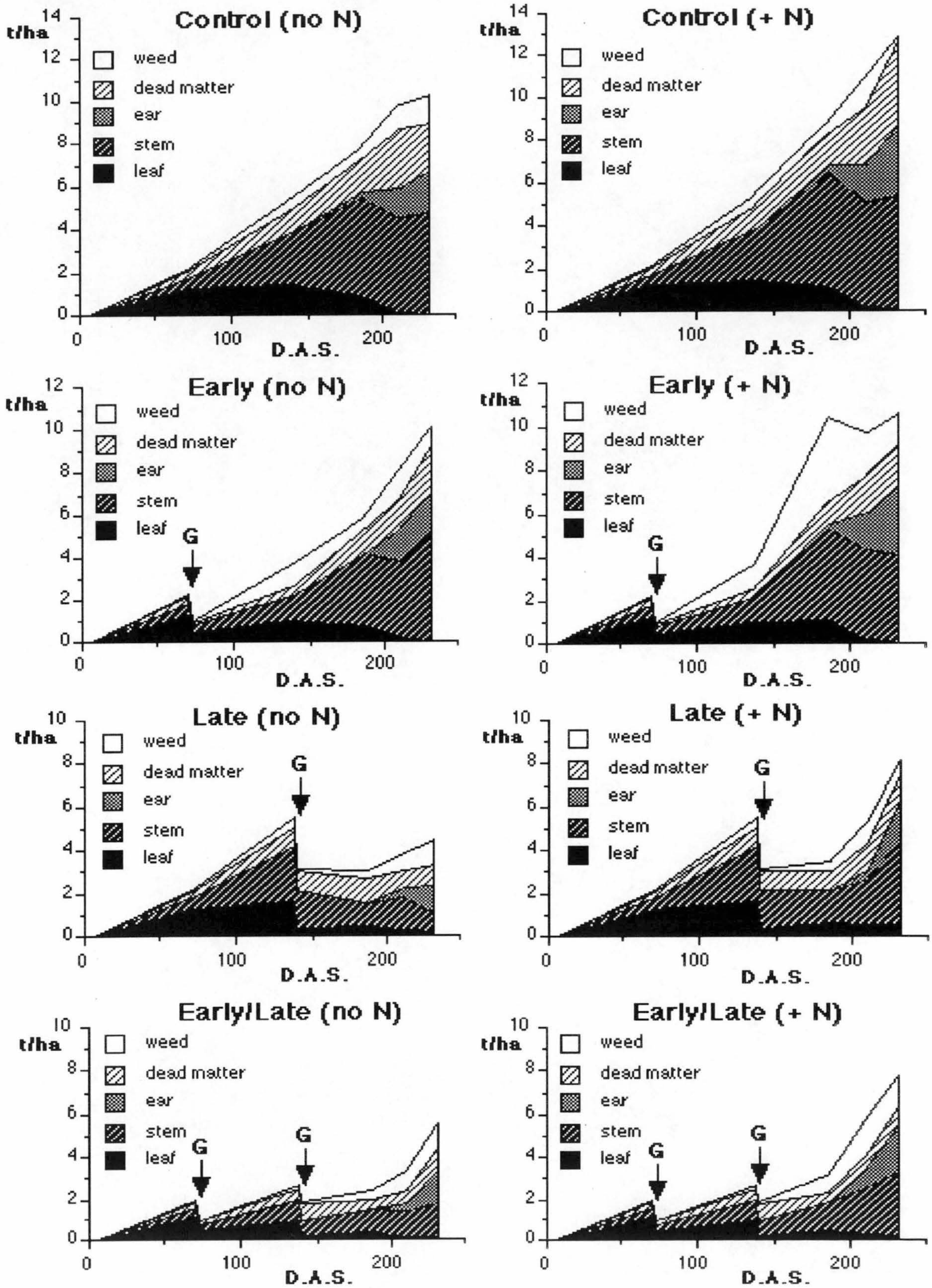
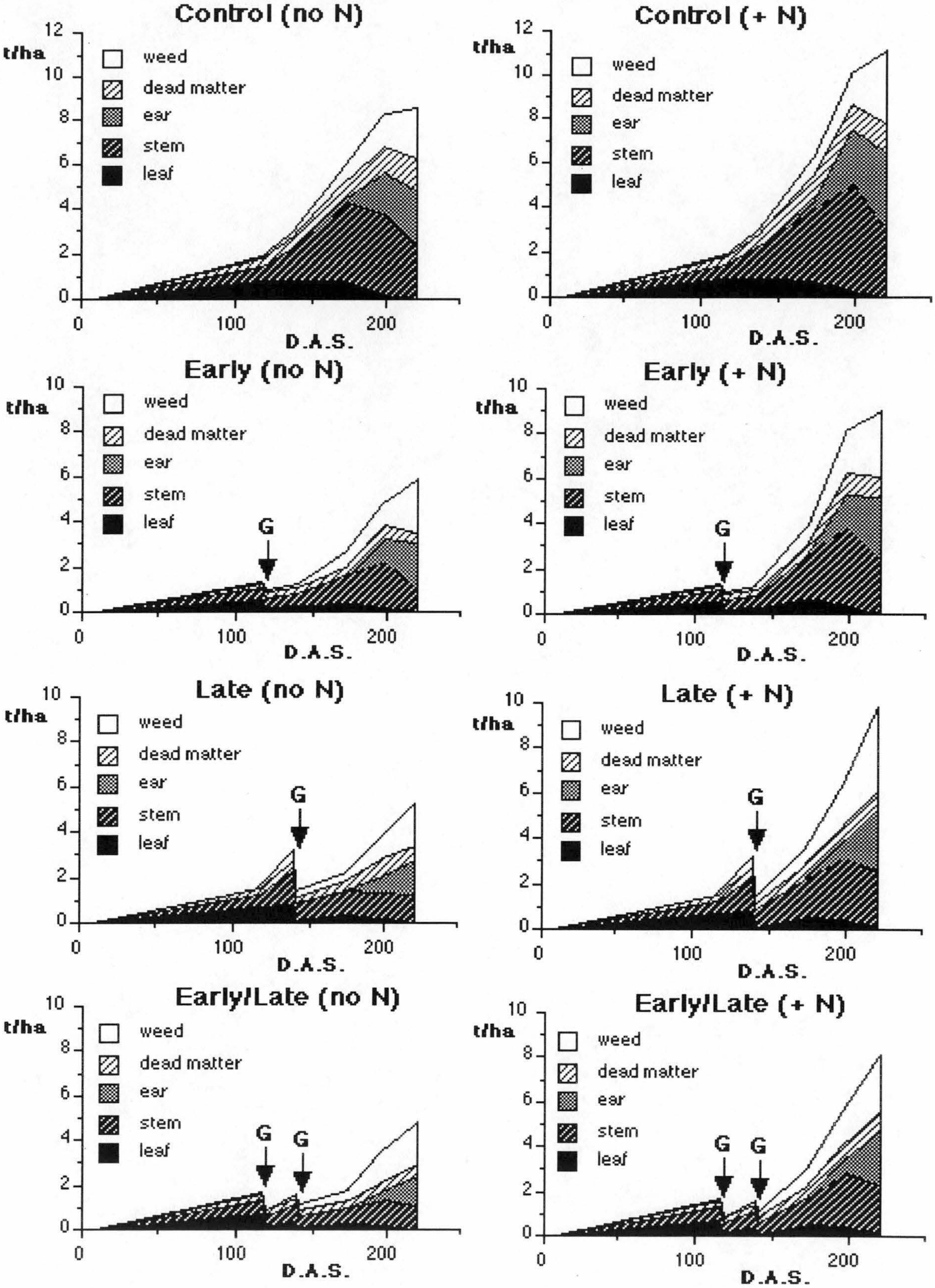


Figure 3.7.3 Third Sowing



3.2.5 Grain Yields

Grain yields for all sowings were below those of the previous season and well below the potential that has been shown for Tasmania (Mendham and Russell, 1987). However for each sowing obvious trends emerged.

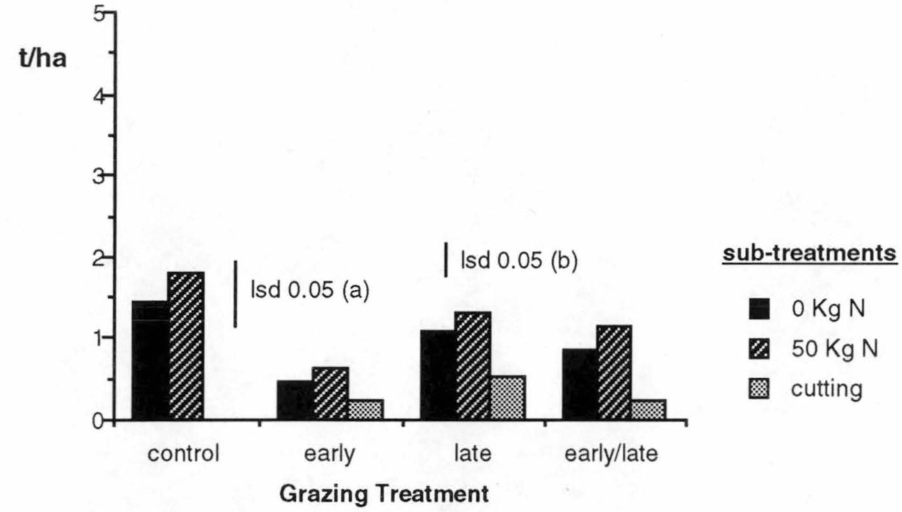
The first sowing had the lowest grain yields for all treatments (fig. 3.8i), with the largest reduction on the early grazing treatment. There was a large variation in the results from different plots, which will be discussed in more detail in a later section on waterlogging.

In the second sowing (fig. 3.8ii), by contrast, early grazing had little effect on grain yield at least in the nil N treatments, but both later grazings caused significant reductions. Again there were substantial differences between plots of the same treatment in different replicates due to waterlogging, although they were not as large as in the first sowing.

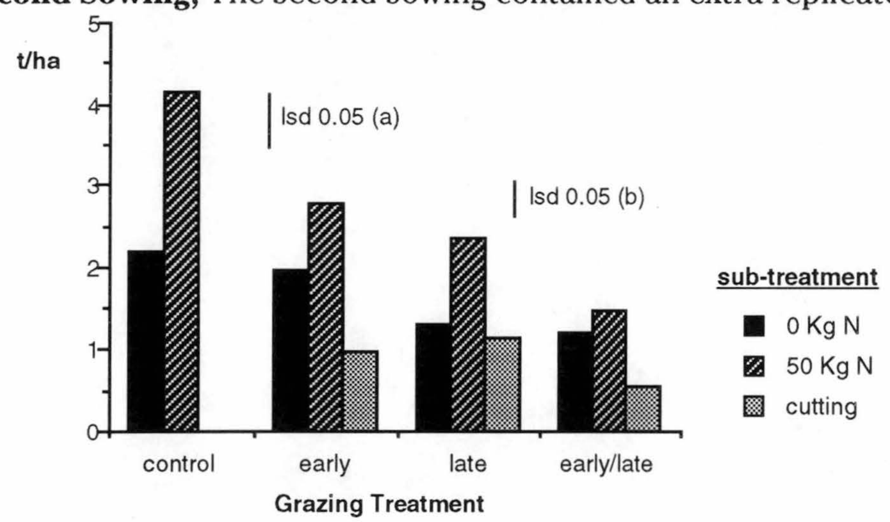
Grazing caused a reduction in grain yields on the third sowing (fig. 3.8iii), but there was little difference between grazing treatments. Yields for the control and early grazing were similar to those of the second sowing (fig. 3.9), however on the other grazing treatments yields were higher than for the second sowing. The general trend was for yield to increase with late sowing (figures 3.9 and 3.10).

Figure 3.8; Grain yields for all treatments for each sowing. Bars indicating LSD's are (a) between grazing treatments and control, (b) between sub-treatments (nil N, plus N, and cutting).

(i) First Sowing



(ii) Second Sowing, The second sowing contained an extra replicate.



(iii) Third Sowing

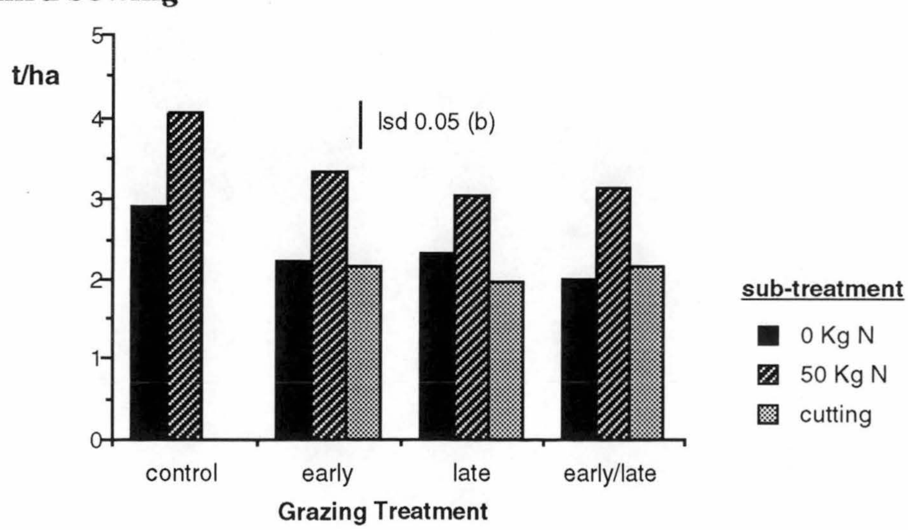
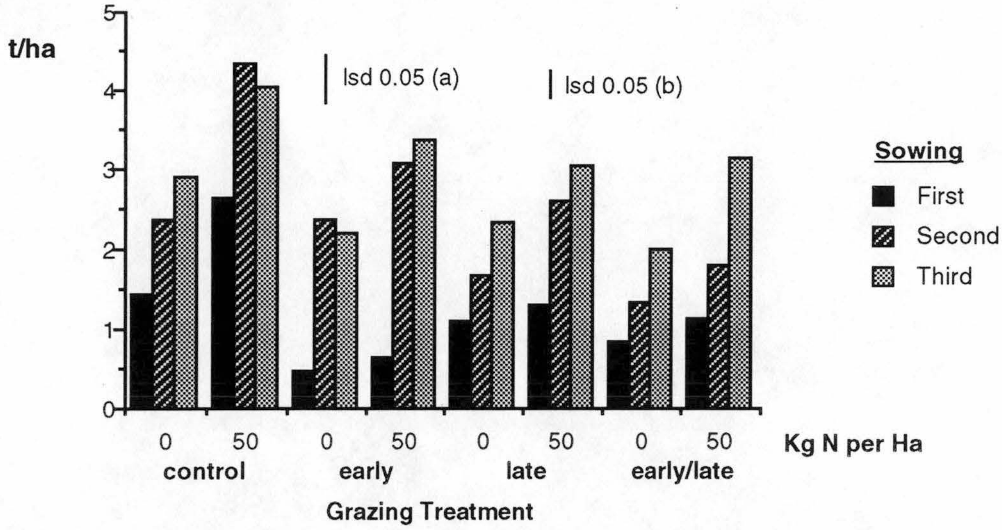


Figure 3.9; A comparison of grain yields on nil and plus N grazing treatments and controls, for all sowings. Bars indicating LSD's are (a) between grazing treatments, (b) between 0 and 50 kg N/ha.



Nitrogen increased yield for all treatments of all sowings (figures 3.9 and 3.10), and while increases within each sowing were similar the exception was the control of the second sowing where the increase was much larger than on other treatments of that sowing. Averaged over the three sowings the trend was for nitrogen to compensate for the effects of grazing (fig. 3.11) although it also boosted yield of the control.

Figure 3.10; Effect of sowing time and nitrogen on grain yields.
The nil N control is included in the mean of cutting treatments

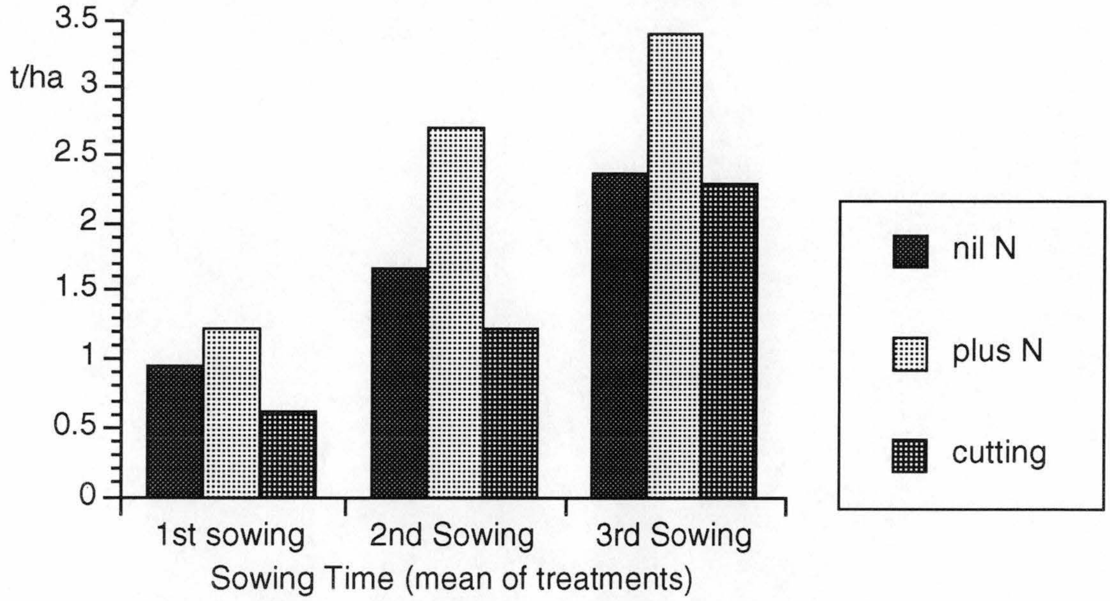
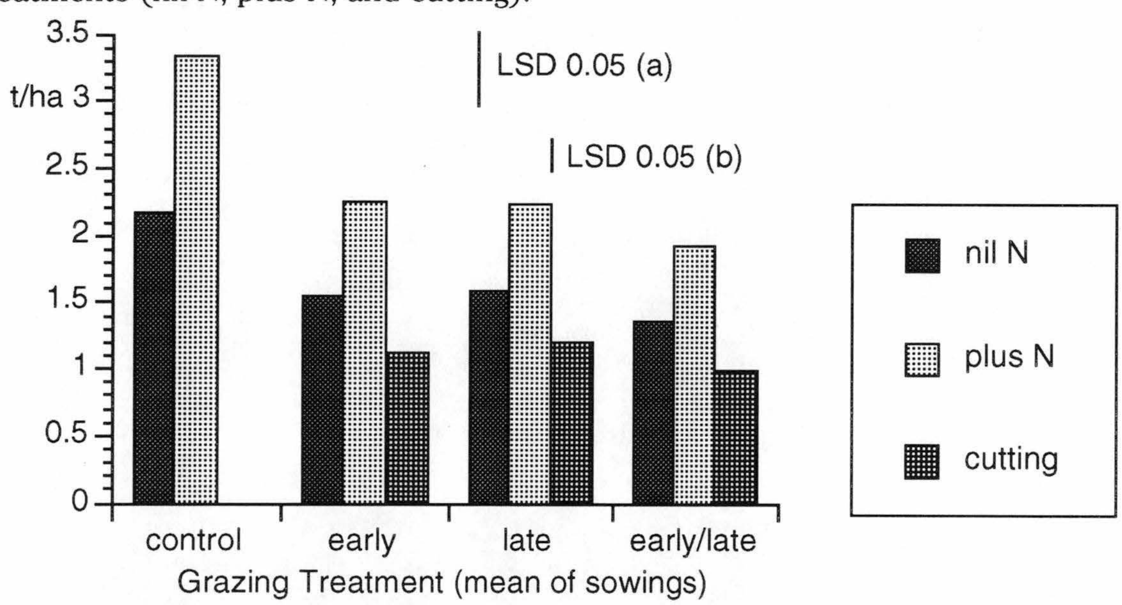


Figure 3.11; Effect of grazing on Grain Yields (Averaged over the 3 sowings). Bars indicating LSD's are (a) between grazing treatments and control, (b) between sub treatments (nil N, plus N, and cutting).



Cutting resulted in much lower yields than the corresponding grazing treatment on the first and second sowings. Cutting yields on the third sowing were not significantly different from those of grazing for all treatments. These results correspond with the trends in forage removal (fig. 3.2) where generally more forage (and hence L) was removed by cutting than by grazing in the first two sowings. On the third sowing cutting removed similar amounts of forage to that removed by grazing, resulting in similar amounts of residual L.

Generally trends in grain yield after defoliation followed the same pattern for both cutting and grazing (fig. 3.11), although reductions due to cutting tended to be more severe.

3.2.6 Waterlogging

Barley is much more susceptible than the other cereals to waterlogging (Cook, 1987), and it can severely reduce both plant dry matter and grain yield (Watson et al, 1976; McFarlane and Wheaton, 1990). Lack of oxygen, due to gas spaces in the soil being filled by water, is the major cause of limited plant growth in waterlogged soils (Setter and Belford, 1990). Waterlogging decreases oxygen diffusion rate, restricts root growth and reduces ion uptake (Sharma and Swarup, 1989). Working with wheat, barley and oats Watson et al (1976) found waterlogging reduced root growth and penetration, the production of tillers and fertile heads and delayed ear emergence and plant maturation. However N application compensated either partially or fully. Visual symptoms of waterlogging damage to the shoots of cereals include reduced growth, wilting, chlorosis (yellowing), premature senescence and leaf drop (Setter and Belford, 1990). Decreased nutrient and water uptake can also occur.

The major symptoms of waterlogging were expressed in the experiment, following the increase in rainfall and decline in mean temperature from mid Autumn (fig. 3.1). The trial plot was laid out at the bottom of a slope which provided a large amount of water runoff in a wet winter. Replicate 1 was nearest to the base of the hill and replicate 3 was the furthest away. Replicates 1 and 2 showed the worst symptoms of waterlogging while replicate 3, being furthest from the base of the hill showed the least. This is illustrated in figure 3.12 which shows the grain yields from each individual replicate and treatment in the first sowing. Yields increase from replicate 1 through to replicate 3.

The symptoms of waterlogging observed were a distinct yellowing of the plants in mid-winter, accompanied by poor growth in comparison to drier plots. Water was noticed to be laying in sheets in patches. Also many grain sites failed to fill, and remained immature.

Figure 3.12; A comparison of grain yields between all plots of the first sowing.

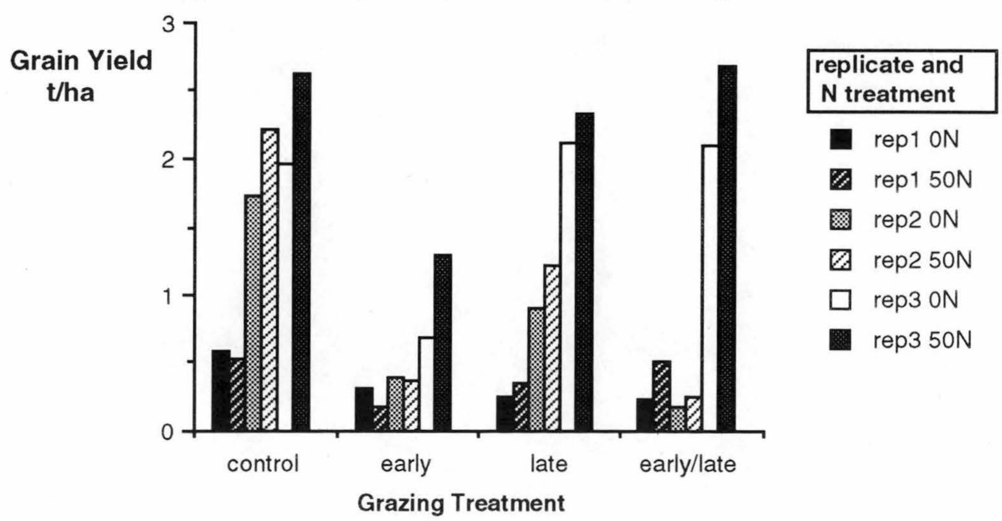
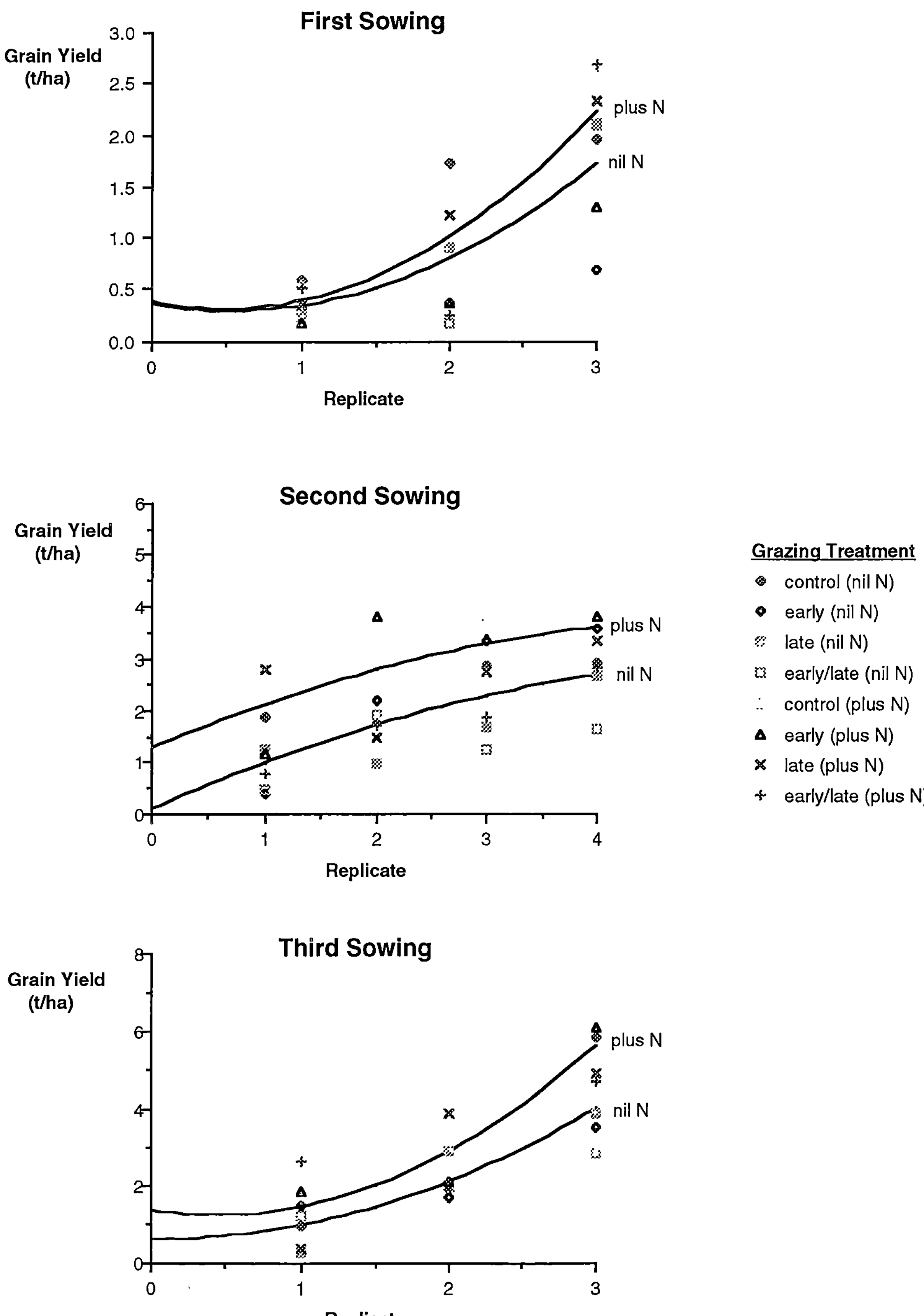


Figure 3.13; Grain yields for all replicates of all treatments with regression lines fitted for mean yield of nil N and plus N



Because of the observed gradation in yields across the replicates, due to waterlogging, regressions were plotted for each sowing time (fig 3.13). The lines on the graphs show averages of either nil N or plus N treatments, and in all sowings the plus N treatment is the higher line. Where waterlogging was the most severe, as on replicate 1, the difference in yields between the control and the grazing treatments was greatly reduced. However the ranking was usually the same. Nitrogen generally increased yields on waterlogged plots, as found by Watson et al (1976), but had a greater effect where waterlogging was not a problem.

Vertigan and Young (see appendix C) reported a similar reduction in grain yield for a Ulandra crop which was grown under waterlogged conditions at Cressy.

3.2.7 Straw Length and Harvest Index

As with grain yield the overall trend in straw length (figure 3.14) was for a reduction due to grazing. Treatments involving late grazing reduced straw length more than the single early grazing. Nitrogen in all cases increased straw length. This was a disadvantage in the control plus nitrogen treatment of the first sowing where the extra straw length contributed to some minor lodging. Straw lengths for all treatments were short in comparison to the previous year.

Straw length remained fairly constant between sowing times (figure 3.15), however nitrogen increased it in the second and third sowings to a far greater extent than in the first. The effect of cutting was generally similar to that of grazing although it caused a slightly greater reduction in straw length in the first two sowings.

Figure 3.14; Effect of grazing treatment on straw length for all sowings. Bars indicating LSD's are (a) between grazing treatments, (b) between sub-treatments.

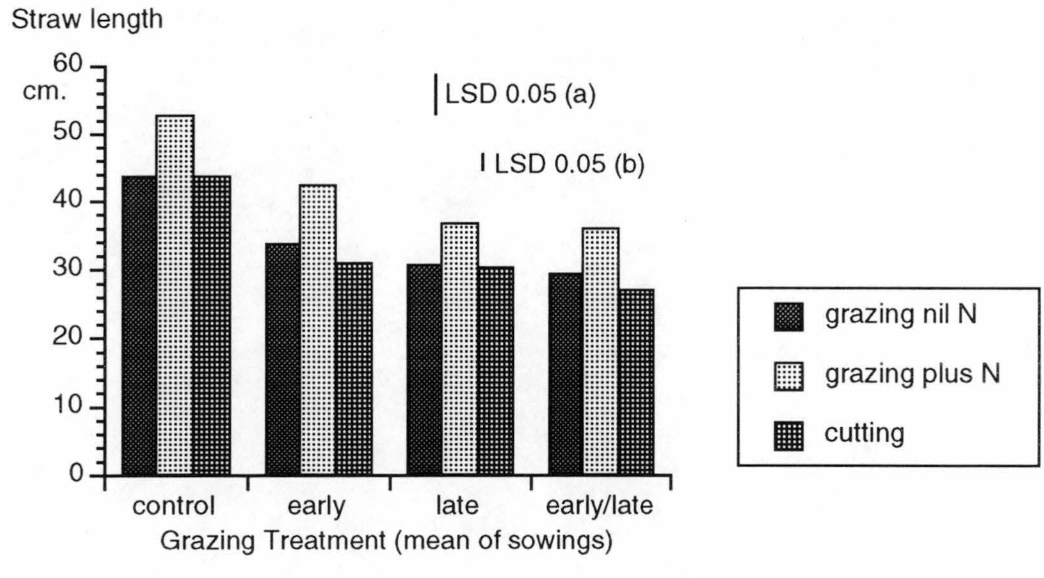
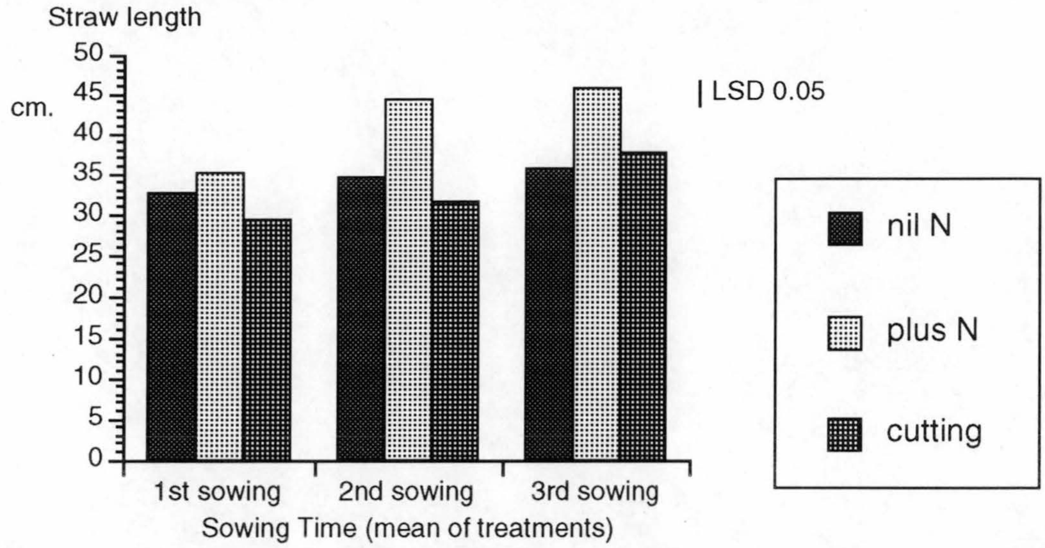


Figure 3.15; Effect of sowing time x nitrogen on straw length. Bar indicates LSD between sub-treatments (nil N, plus N and cutting).



Harvest index was surprisingly low for the first two sowings (figure 3.16), the trend being for an increase with later sowing, in line with the increase in grain yield. Increasing the level of grazing generally increased the harvest index at all sowing times although this trend was not even.

Nitrogen application did not greatly affect harvest index (fig. 3.16) and is averaged with the nil N treatments in figure 3.17 which shows the overall trend in harvest index across the grazing treatments. Increased grazing led to higher harvest index, largely due to the reduced vegetation following grazing.

Figure 3.16; Harvest Index for all experimental treatments

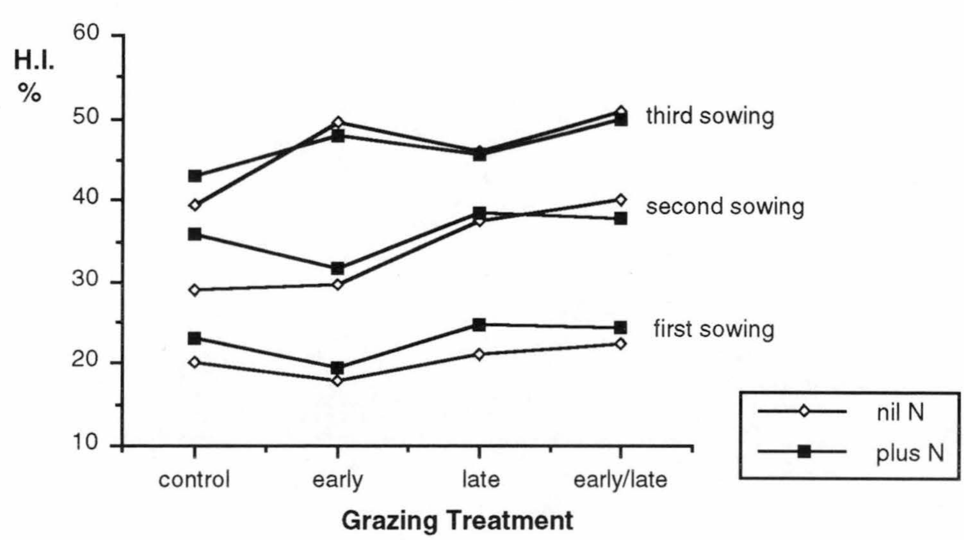
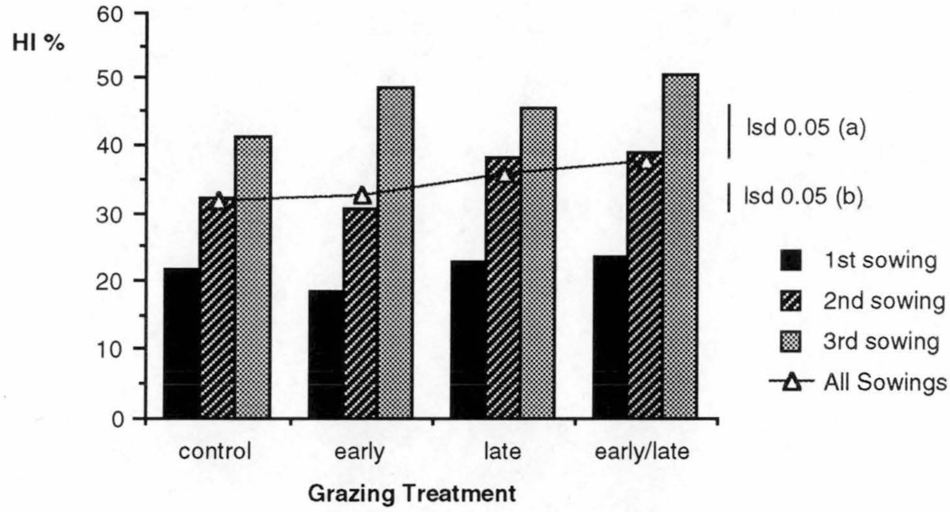


Figure 3.17; The effect of grazing treatment on harvest index (mean of Nitrogen levels) Bars indicating lsd (0.05) are, (a) between sowings ,and (b) between grazing treatments



Cutting decreased harvest index at each sowing time (figure 3.18), due to the greater amount of forage removed, and decreased harvest index below the level for grazing for each defoliation treatment (figure 3.19). With sowing times the trends in harvest index for both cutting and grazing are similar, but this is not the case with different grazing treatments.

Figure 3.18; Harvest indices of cutting and grazing treatments (mean of grazing treatments) at each sowing time. Bars indicating lsd 0.05 are, (a) between sowings, and (b) between sub-treatments

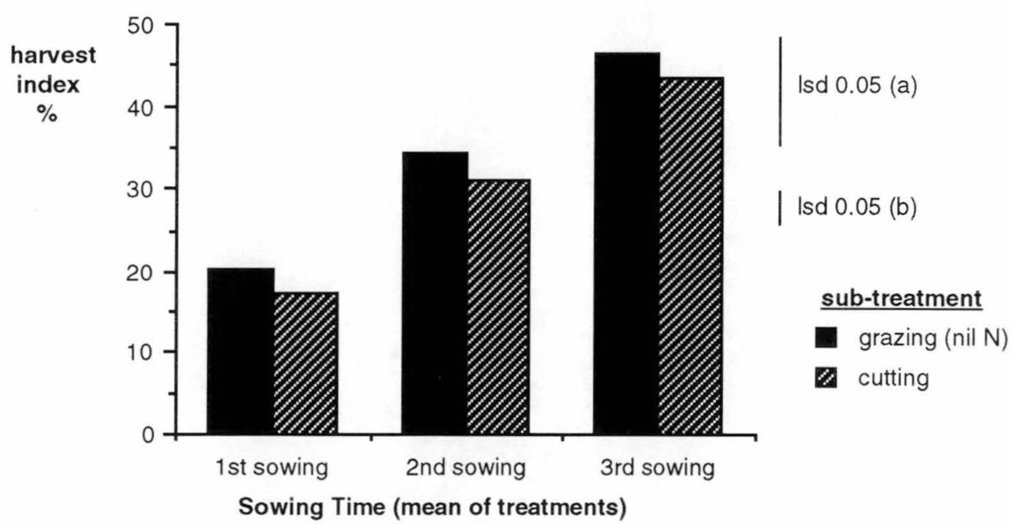
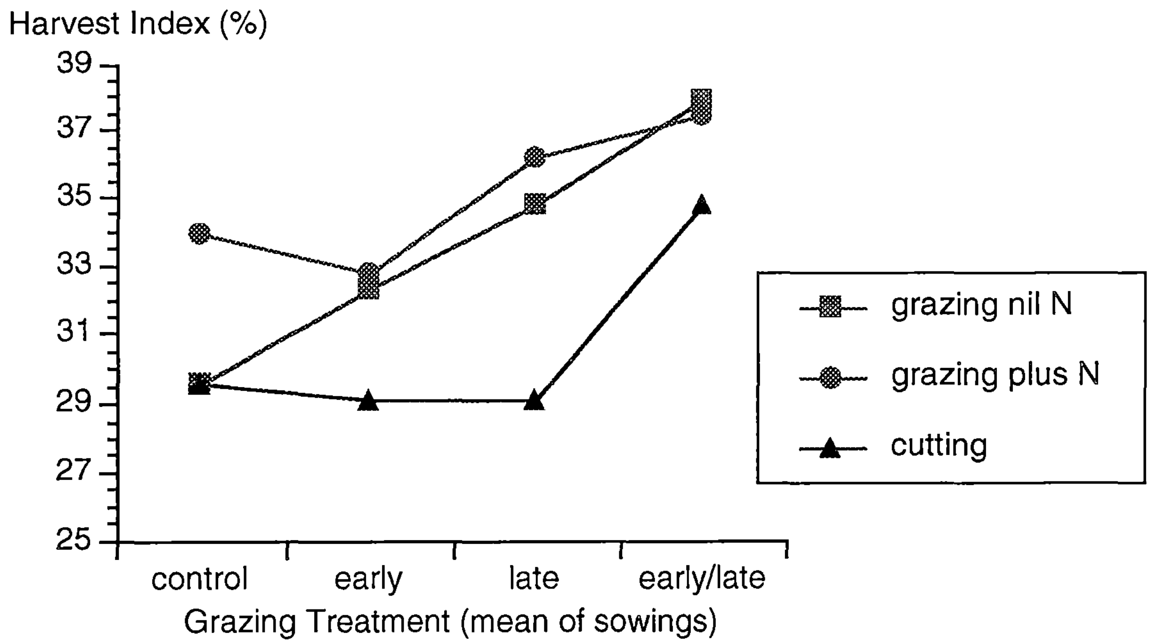


Figure 3.19; Change in harvest index with differing defoliation treatment.



3.2.8 Components of Yield

As happened with dry matter and grain yield the values of the components of yield were below those normally expected. Again this is most likely due to the effects of poor crop growth after waterlogging. It was noticed during the processing of harvest samples that there appeared to be many unfilled grains, this being more apparent in the first two sowings. These unfilled grains are not included in the results as they were lost as chaff during threshing.

When averaged across the three sowings, grazing reduced the number of ears per square metre (figure 3.20i), and whilst there was very little difference in effect among the three grazing treatments, ear number per square metre was slightly higher in the late grazing. The effects of the sub-treatments of added nitrogen or cutting were similar for all treatments, nitrogen increased ears/m^2 while cutting reduced ear number below that for the corresponding grazing treatment. The increase in ear number due to N would be from enhanced tiller survival, as the number of tillers is determined just prior to the beginning of stem elongation, being just before N application. Due to the greater amount of forage removed by cutting, tiller survival on the cutting treatment would have been lower than that for grazing, resulting in lower ear number.

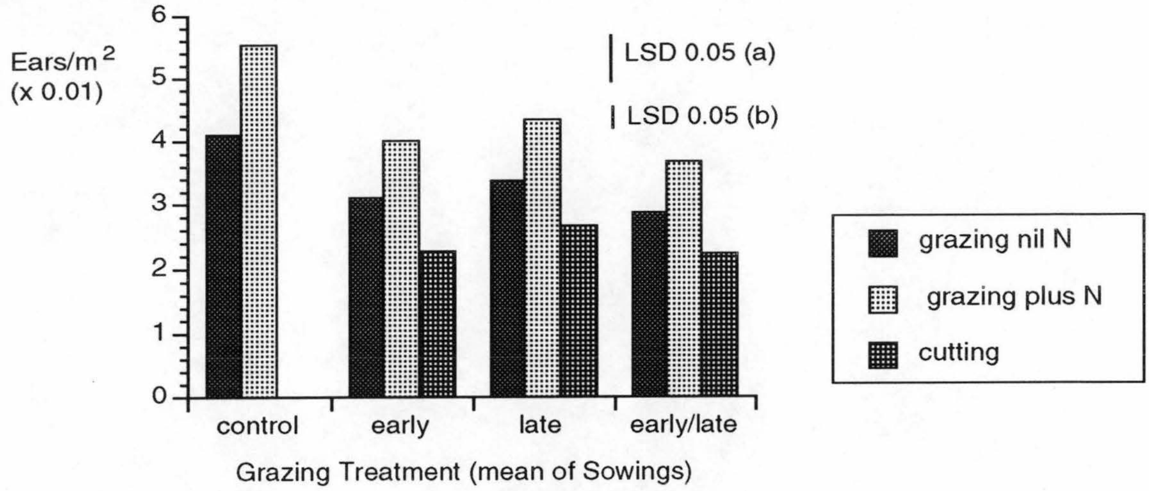
While grazing also reduced grain number per ear (fig. 3.20ii), the reduction was progressively greater with increased grazing pressure. Again nitrogen increased grains/ear, compensating for losses due to grazing. Cutting gave fewer grains/ear than than the comparable grazing, the biggest reduction being with the late grazing. All grain numbers/ear are low, at around half those of the previous year.

The combined effect on ear numbers and grains/ear can be seen in figure 3.20iii, where grazing reduced grain number but nitrogen compensated for the reduction. Grazing twice i.e. early/late reduced grain number slightly more than either of the single grazing treatments. Cutting gave fewer grains than grazing, due to greater L removal and hence less assimilate, but showed the same trend as grazing.

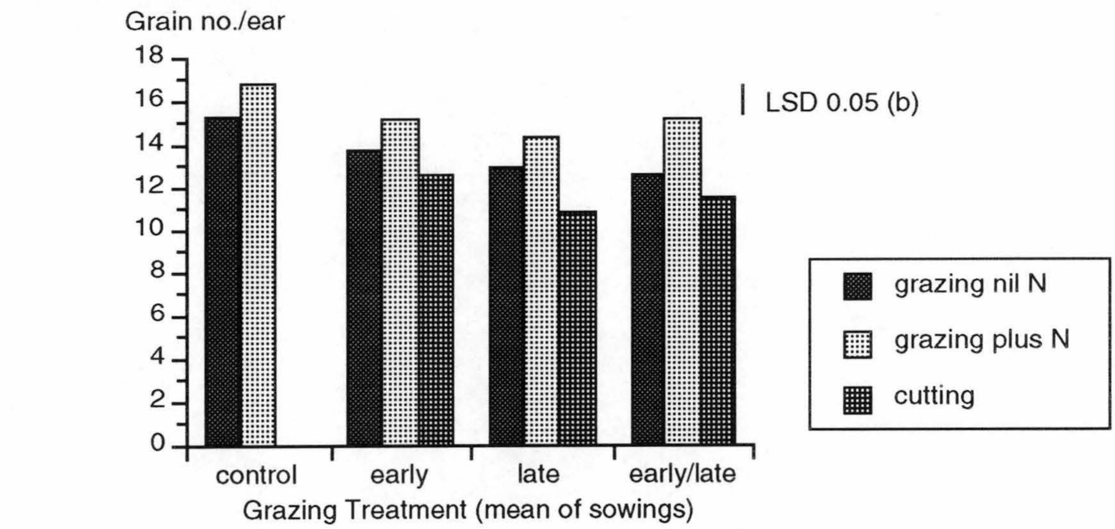
There was a trend for all sub-treatments to give a slightly higher ear number with late grazing than the other grazing treatments, although the effect on grain number was cancelled out by lower values of grains/ear. The increase would be due to an increase in tiller numbers, which Abdul-Rahman (1988) concluded resulted from the removal of apical dominance when the more advanced shoot apices were lost during grazing.

Figure 3.20; Effect of Grazing on i) ear number, ii) grains/ear, and iii) grains/square metre. Bars indicating lsd's are (a) between grazing treatments and (b) between sub-treatments (nil N, plus N and cutting treatments).

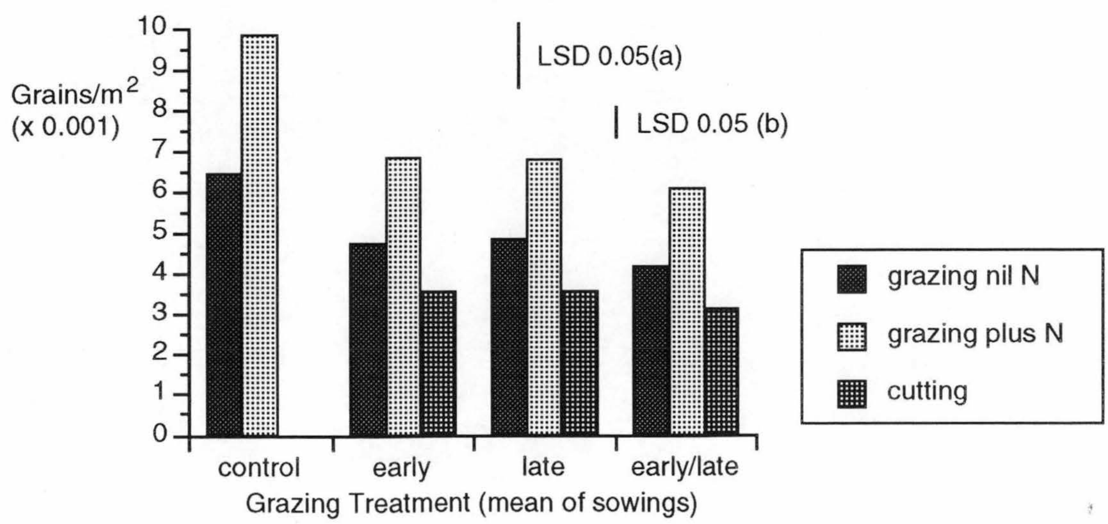
i) Ear Number



ii) Grain Number per Ear



iii) Grains/m²

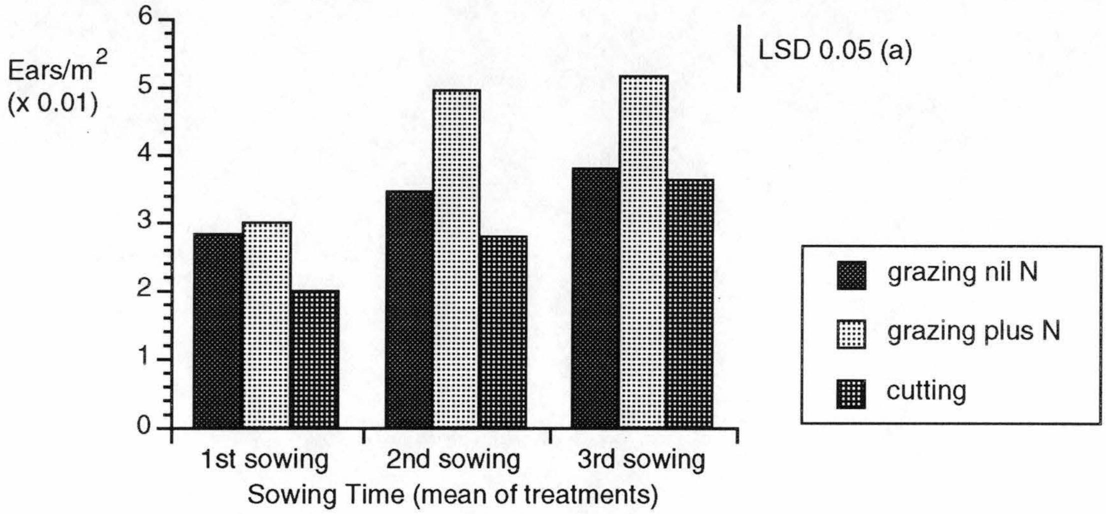


As with grain yield, grain number (fig. 3.21iii) was increased with later sowing, mainly due to an increase in grains/ear (fig. 3.21ii) as ears/m^2 (fig. 3.21i) showed a smaller effect. The effects of nitrogen application generally followed the same trends at each sowing, increasing ears/m^2 (fig. 3.21i), grains/ear (fig. 3.21ii), and consequently grain number (fig. 3.21iii). The smaller increase in ears/m^2 with the first sowing may in part be due to N being applied too late to affect tiller number.

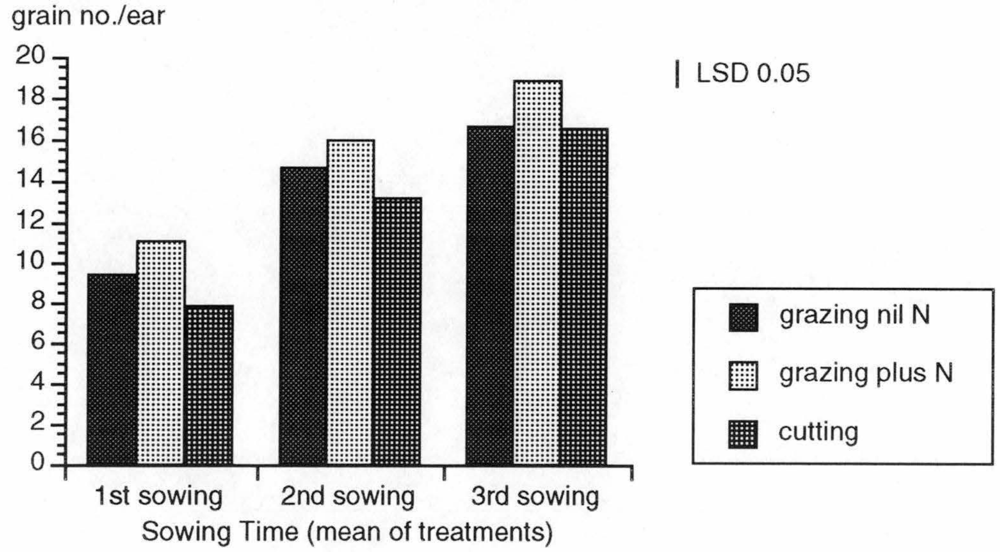
Cutting instead of grazing resulted in fewer ears/m^2, grains/ear , and consequently grains/m^2 at the first and second sowing but was similar in effect to grazing at the third. This trend is the same that occurred with grain yields.

Figure 3.21; The effect of sowing time on i) ear number, ii) grains/ear, and iii) grains/square metre; for each sub-treatment (N.B. grazing treatment mean includes the control)

i) Ear Number. Showing LSD 0.05 for sowing time x sub-treatment interaction



ii) Grains/ear. Showing LSD 0.05 for between sowing times.



iii) Grains/m² Showing LSD 0.05 for sowing time x sub-treatment interaction

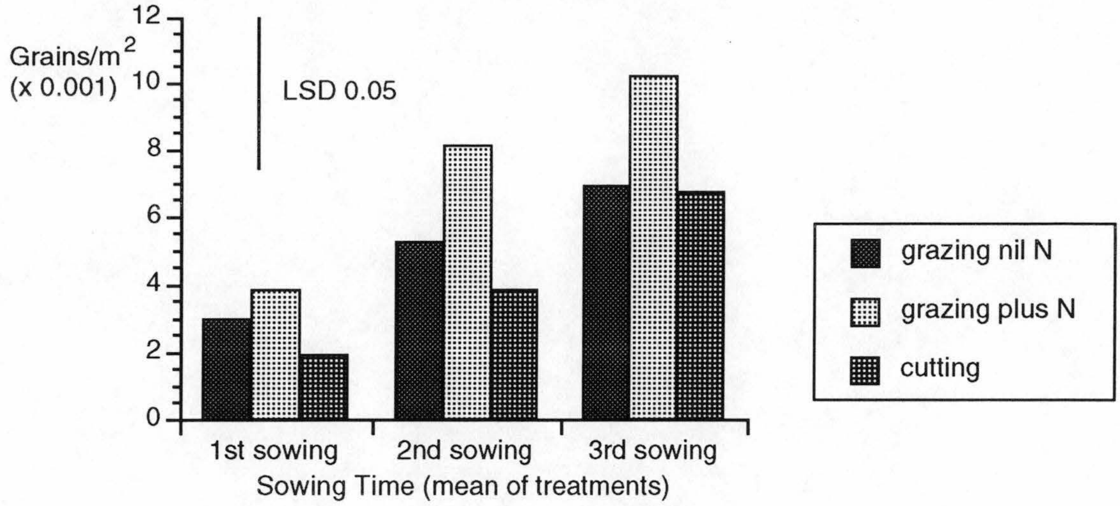
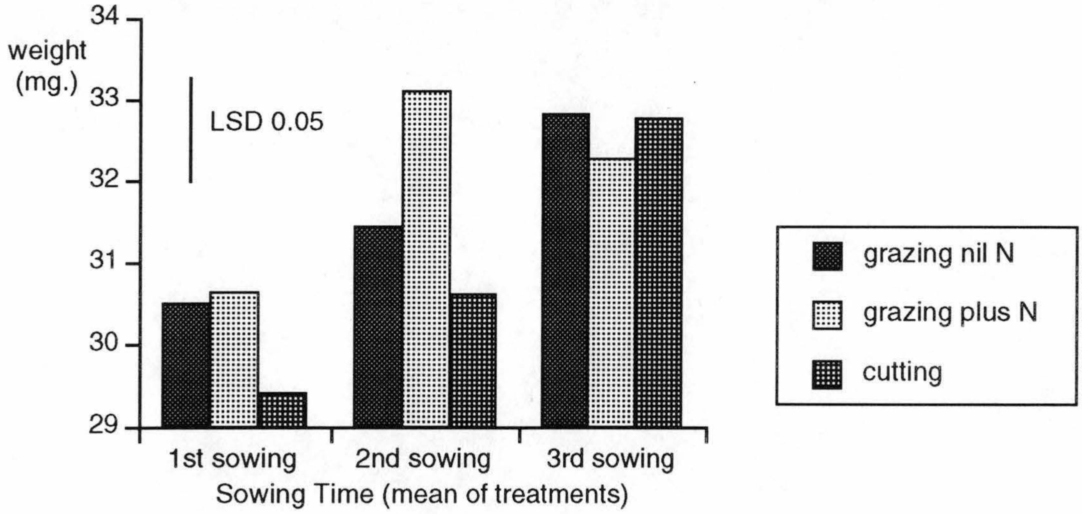


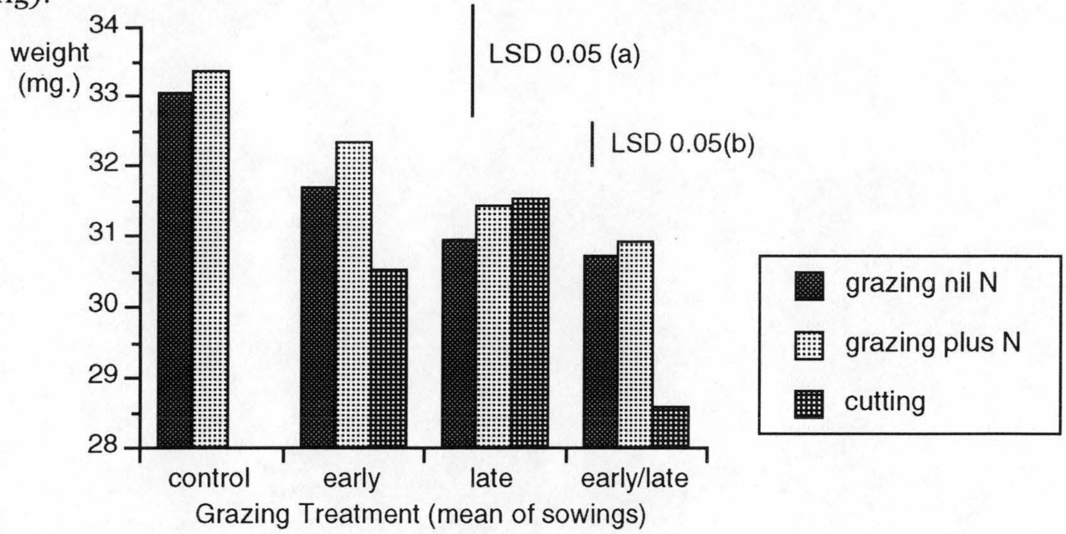
Figure 3.22; Effect of sowing time on individual grain weight.
Bar indicating LSD 0.05 is for sowing time x sub-treatment interaction.



While the variation in individual grain weight was not large it tended to increase with later sowing (figure 3.22). Nitrogen application increased individual grain weight for the first two sowings, however reduced it for the third sowing. This is possibly due to nitrogen having increased grains/m² such that the available nutrient supply was spread too thinly, resulting in lower individual grain weights although total grain yield was increased. Cutting, as with the other yield components, reduced individual grain weight at the first and second sowings but not the third. The lower weights in the first sowing reflect the slow growth late in the season and lower final dry weights experienced with this sowing, which resulted in lower levels of assimilate for grain fill.

Grazing decreased individual grain weight (figure 3.23) with the decrease being greater with heavier grazing. Nitrogen increased individual grain weight but this failed to fully compensate for the effects of grazing. Cutting tended to give lower weights than grazing, except with late grazing where cutting had reduced grain number, therefore there was enough assimilate to fill available grain sites to about the same level as on grazing treatments.

Figure 3.23; Effect of grazing on individual grain weight. Bars indicating LSD 0.05 are (a) between grazing treatments, and (b) between sub-treatments (nil N, plus N, and cutting).



It is noticeable that in most treatments, including controls, yield component values are below those generally expected in a normal barley crop. Grain number per head, for example, is in most cases well below that expected in Ulandra. This reduction in yield components accords with the effects of waterlogging on barley noticed by others.

Grazing where it affected yield components seems to have had the most effect in reducing the number of ears per m^2. The addition of nitrogen appears to have generally increased most of the yield components and always acted to increase grains/m^2. The reduction in grains/m^2 and grains/ear where it occurred may in part be due to the effects of waterlogging. The figures only show the number of fertile grains/m^2 and grains/ear, however especially with the first sowing there appeared to be a large number of infertile grains/ear.

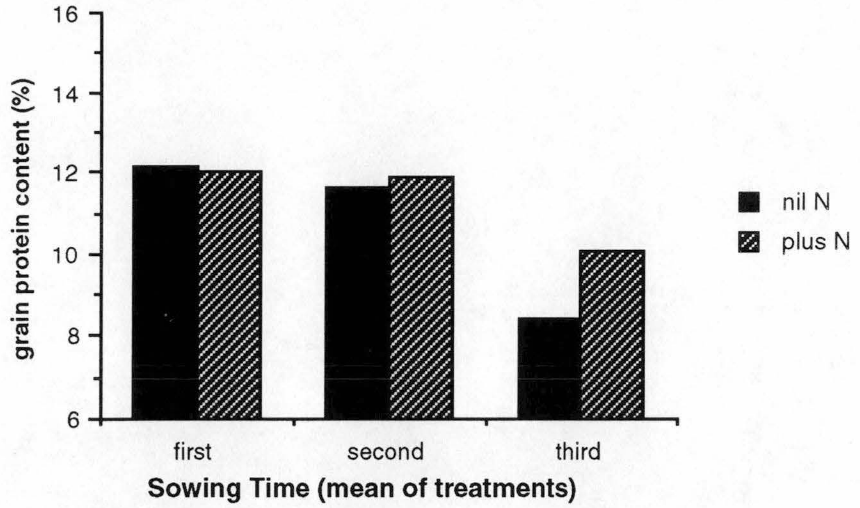
With the first grazing, early grazing had the largest negative effect on the yield components, which goes against the overall trends for the other sowings. This was possibly due to extra stress caused by waterlogging, which prevented recovery in L following grazing.

Cutting in general appeared to reduce the yield components below that of the comparable grazing, due to a greater loss of plant dry matter and hence L. However, trends with cutting still followed those of grazing, therefore cutting may be of use in predicting trends due to grazing.

Reduction in L following grazing, resulting in lower availability of assimilates, appears to have been the major factor in reductions in the yield components. Removal of shoot apices appears to have been largely avoided.

3.2.9 Grain Protein

Figure 3.24 ; Effect of sowing time on grain protein content (%).



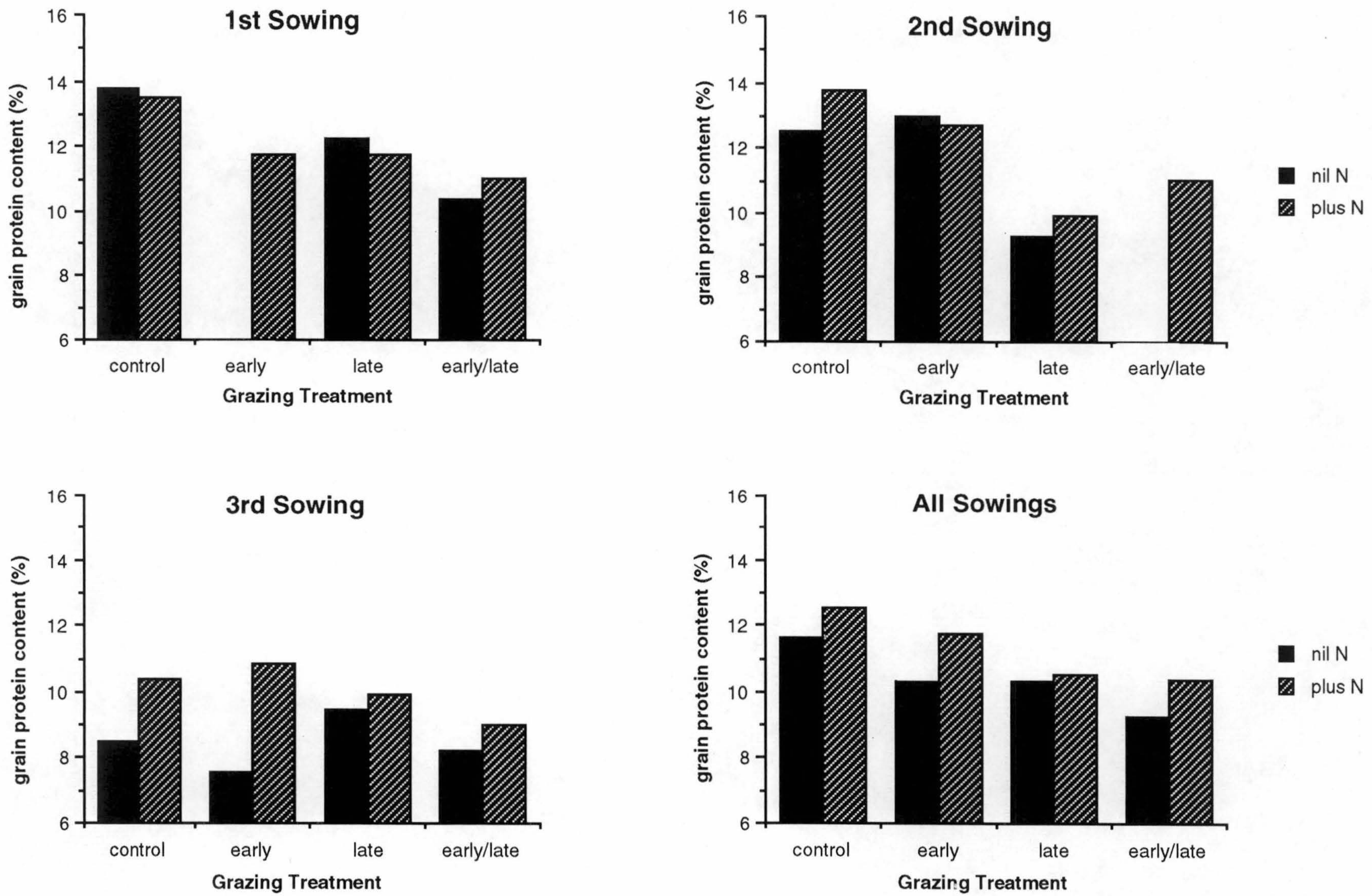
Grain protein content is presented in figures 3.24 and 3.25. Samples were taken from one plot in each replicate, therefore it was not possible to perform any statistical analysis on the results. As well some figures are missing, however an idea of the trends in grain protein content can be gained from the figures.

Grain protein levels were high in the first two sowings but were reduced in the third (figures 3.24 & 3.25). This reduction may be related to the lower L's on this sowing. Grazing generally decreased grain protein content, a trend more obvious when averaged across all sowings (fig. 3.25), while the trend with N application was for an increase. In some cases N fully compensated for the effects of grazing.

Once again seasonal differences are apparent as the grain protein in 1988 differed from that of the comparable (third) sowing in 1989, protein level being consistently higher in 1988 for all grazing treatments. The trend for N application to increase grain protein was common to both seasons, however in 1988 grazing did not reduce it.

As a result of the waterlogging that occurred in the 1989 season, the ability of the crop to fill grains was impaired (seen in the reduction in grain size and grain number). Also the ability to take up nitrogen and produce grain protein appeared to have been affected.

Figure 3.25 The effect of sowing time, grazing treatment, and nitrogen on grain protein



3.2.10 Choice of Sowing Time

The results from this season's experiments showed that the later sowing time generally gave the highest grain yield regardless of grazing treatment (figure 3.9) although some of this difference must be attributable to the effects of waterlogging, which was more serious on the earlier sowings. However the difference in grain yields on the early grazing treatment of the second and third sowings was quite small, suggesting that there is some flexibility in the choice of sowing date if grazing is intended.

Generally it can be concluded that sowing time did not effect the amount of forage potentially available for grazing but did alter the time of its availability. The first and second sowing times allowed late Autumn or early winter grazing while there was not sufficient feed on the third sowing for grazing until late winter.

The ability of the crop L to recover following grazing was of great importance in maximising final grain yield as it was most reduced where L recovery was poor. Nitrogen application assisted recovery of L to varying degrees, however even where N appeared to only marginally increase L final grain yields were increased. As leaf nitrogen is highly correlated with CO_2 assimilation rate in leaves (Sinclair and Horie, 1989), the addition of N would have increased assimilation rate even at low L's.

A major inhibiting factor in crop recovery for this season was the occurrence of waterlogging, which affected the first and second sowings more than the third. Waterlogging conditions were worst in mid winter, following early grazing on the first and second sowings, and severely affected recovery. The worst of the waterlogging was over during the recovery period following grazing of the third sowing. Waterlogging caused yield reductions on similar experiments at Cressy (Young and Vertigan, see appendix C). Arranging sowing and grazing time to avoid the worst of waterlogging may be difficult due to seasonal differences and grazing needs which may coincide with the occurrence of waterlogging. N improved grain yields on all waterlogged plots, but was more effective where waterlogging did not occur.

Where grazing is of more importance to a farmer than grain yield sowing time would be decided on the basis of when the forage is most needed. However if grain yield is equally important then on the basis of this seasons experiments the late March sowing should be ruled out. The experiment would need repeating, however, on a better-drained site.The April sowings however, provided they were grazed once and grazing was followed by nitrogen application, could be grazed successfully while maintaining grain yields to the level of an ungrazed nil N treatment. This gives a choice of safe grazing times from early winter through to early spring.

CHAPTER FOUR

SEASONAL DIFFERENCES IN THE EFFECT OF SOWING TIME, GRAZING TREATMENT AND NITROGEN APPLICATION ON THE FORAGE AND GRAIN YIELD OF WINTER BARLEY

Seasonal differences in the effects of grazing on the grain yield of barley are common. The 1989/90 season was affected badly by waterlogging whereas in the 1988/89 season it was not as important. To gain a better perspective on seasonal differences it was decided to run a similar experiment in the 1990/91 growing season. This chapter compares those results with those from the previous two seasons.

4.1 Materials and Methods

Once again the barley cultivar Ulandra was sown, on only two sowing dates, April 3rd and April 27th, corresponding closely with the second and third sowings in 1989. Angus yearling heifers were again used to graze the plots, however no cutting treatments were used this year. The four main grazing treatments were once again;

i) control; no grazing.
ii) early grazing.
iii) late grazing.
iv) early/late grazing; a combination of (ii) and (iii).

Due to the poor germination rate of the seed available (60%), the sowing rate used was 160 kg/ha. The seed was sown with superphosphate at a rate of 250 Kg/ha.

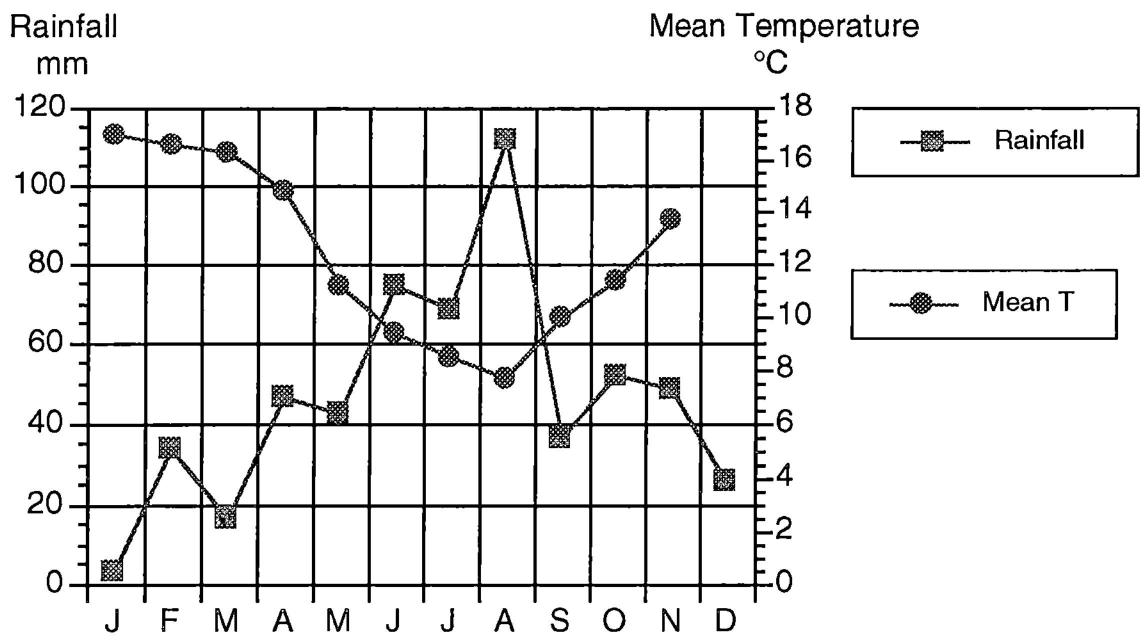
The site chosen at Thirlstane was on krasnozem soil and had a long cropping history. The previous crops on this site had been onion followed by peas for processing.

4.1.1 Rainfall and Temperature

The rainfall peak was later in the year this season (fig. 4.1) than the two previous seasons, not occurring till August, allowing the crop to develop without being affected by waterlogging. As a result of the weather pattern and the site, the ground was firm and dry when grazed and little pugging damage occurred.

The pattern in mean temperature was similar in all three seasons, although June of 1989 was noticeably below that in the other seasons.

Figure 4.1 Rainfall and Temperature for 1990



4.1.2 Sampling

Samples of 0.5 m^2 were taken from all plots before grazing and from grazed plots after each grazing to determine changes in plant dry matter. Grazing height was measured at at least 10 points in a plot and an average was calculated. Random samples of plants were taken from plots for dissection to estimate stage of apex development, apex length, and height of the apex above the base. Tiller number and stage of plant development were also estimated from these samples. A small number of plants were sampled after the completion of all grazing to get an estimate of the proportion of shoot apices removed by grazing. Harvest samples were taken, as in previous seasons, to calculate grain yield, straw length, harvest index, and components of yield. Harvest was carried out between December 29th and January 1st.

4.1.3 Statistical analysis

Statistical analysis was done using split/split plot ANOVA as in previous years.

4.2 Results and Discussion

4.2.1 Grazing dates

The dates of grazing in 1990 are shown in table 4.1, below.

Table 4.1 Grazing Dates (1990)

	Early April Sowing	Late April Sowing
early grazing	30/7 - 1/8	7/8 - 13/8
late grazing	23/8 - 26/8	7/9 - 9/9

The number of days after sowing for these grazings and a comparison with grazing times in the two previous seasons can be seen in table 4.2, below. Grazing times for each sowing were generally the same for each season, the exception was the early April sowing which had sufficient forage for grazing a month earlier in 1989 than 1990. The slower early growth of this sowing in 1990 may be due to the lower rainfall in Autumn compared to the two previous seasons. The variation in the length of time taken for each grazing treatm,ent was due to the weather conditions during grazing rather than any variation in stocking rate.

Table 4.2 Grazing Time (days after sowing)

	Late March Sowing		Early April Sowing		Late April Sowing	
	1st grazing	2nd grazing	1st grazing	2nd grazing	1st grazing	2nd grazing
1988					103-104	144-148
1989	62-73	142-144	66-71	136-140	116-118	140-141
1990			118-120	142-145	102-108	133-135

4.2.2 Height of grazing in relation to shoot apex

The height of defoliation (or grazing) in relation to the height of the shoot apex is shown in figure 4.2. Both the apex height and defoliation height are averages taken from a number of samples, however in general the defoliation height was above the level of the shoot apices. The exception was the single late grazing of the late April sowing. The effect on the shoot apices is illustrated in table 4.3 below which gives an estimate of the percentage removed by grazing. It can be seen that a large number of mainstem apices were removed by the late grazing treatment of the second (late April) sowing.

Figure 4.2; Apex height in relation to days after sowing for both sowing times. The height of defoliation of the single late grazing (L) and the second grazing of the early/late grazing (EL) are marked.

1st sowing 1990(early April) 2nd sowing 1990(late April)

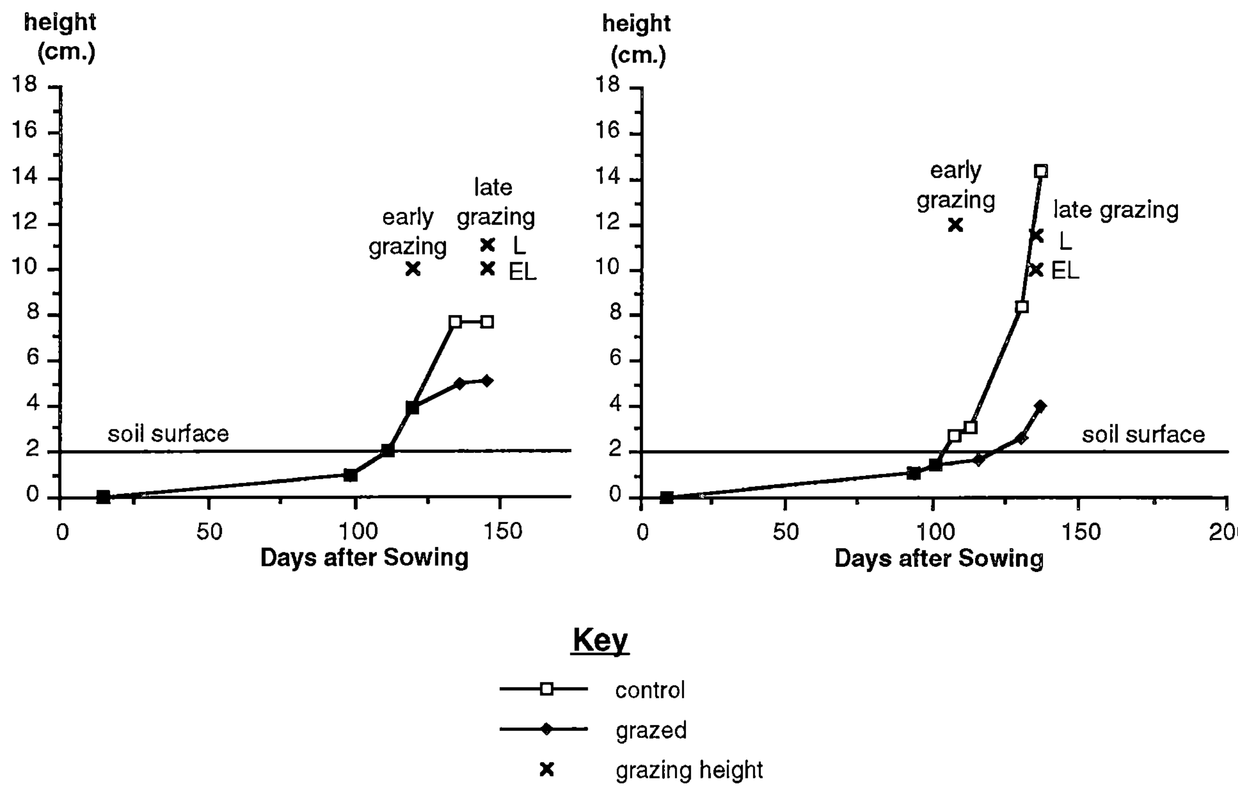
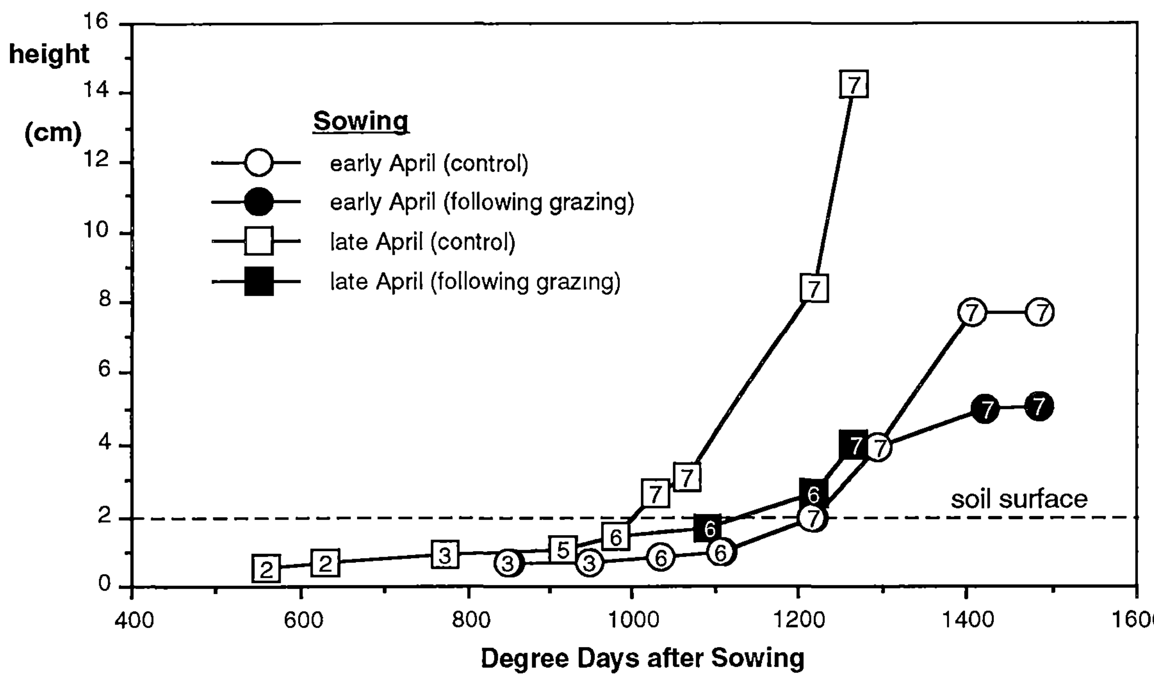


Table 4.3 An estimate of the percentage of shoot apices removed by grazing (nil removed from early grazing).

Sowing	Treatment	mainstem apices removed	tiller apices removed	Average no. of tillers per plant
first	late	14.3%	6.7%	4.3
	early/late	20.0%	0.0%	3.8
second	late	75.0%	15.2%	4.1
	early/late	0.0%	14.3%	3.2

Figure 4.3; The stage of development and height of the shoot apex in relation to the base of the plant, in degree days after sowing, for both sowings in 1990/91



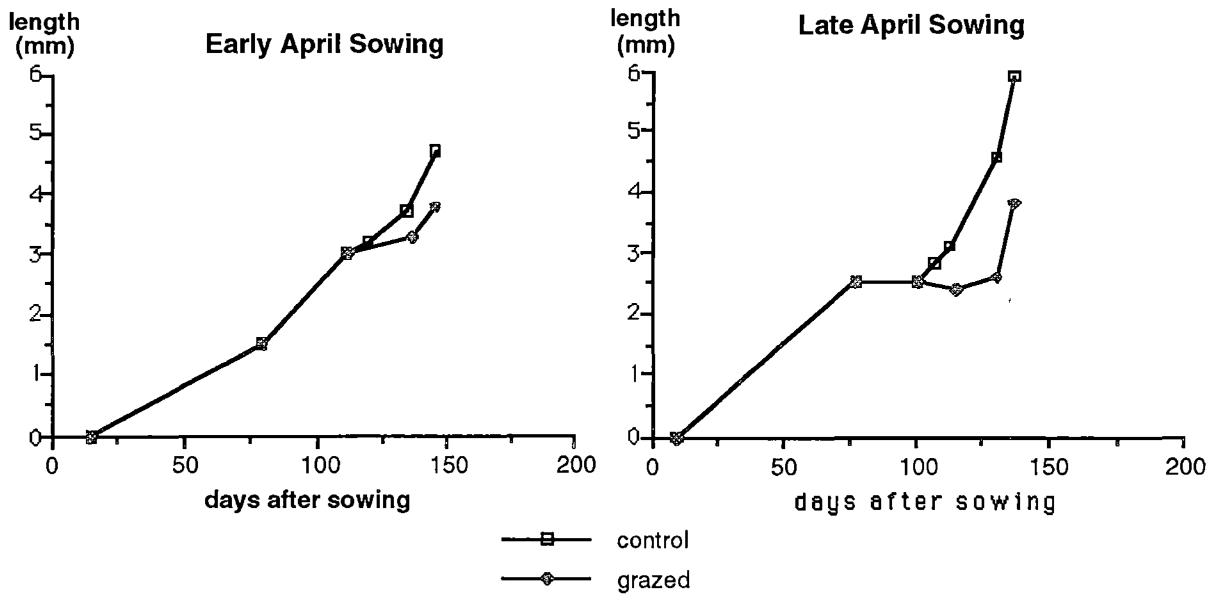
stage of apex development
1) vegetative
2) double ridge
3) triple mound
4) glume primordium
5) lemma primordium
6) stamen primordium
7) awn primordium

Accumulated day degrees was calculated using air temperature as a basis. It is possible that soil temperature may have been different and therefore pattern of development of the shoot apex while below the soil surface may have been slightly different to that presented on the graph.

Development of the shoot apex in the early April sowing was delayed in comparison to the late April sowing, requiring more accumulated day degrees from sowing to reach the same stage of development and apex height (fig. 4.3). This was probably due to dry conditions which slowed seedling emergence (7 days later than the normal 9 days). The shoot apex had reached the late stamen primordium (6) to early awn primordium stage (7) at the beginning of rapid stem elongation.

While grazing delayed shoot apex development in the late April sowing, it did not delay it in the early sowing, as it was not carried out until the apex had already reached the awn primordium stage. However, grazing slowed the rate of elongation and may ultimately have reduced the number of grain sites on the developing ear. This is supported by the effect of grazing on the elongation of the developing ear (fig. 4.4).

Figure 4.4; The effect of grazing on length of the developing ear, prior to second grazing.

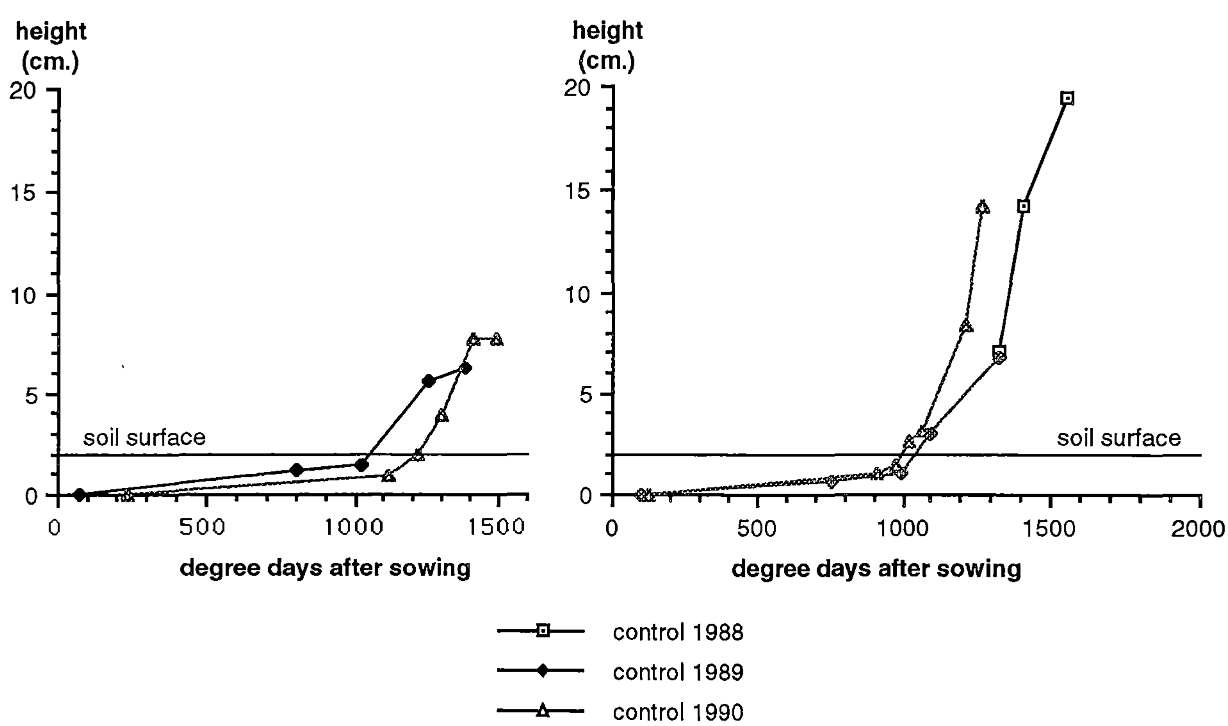


As with development stage, the rate of elongation of the developing ear initially slowed after grazing in both sowings, but then increased again, possibly resulting in fewer potential grain sites. This may have been due to the decrease in leaf area after grazing, which would have reduced available assimilate and may have caused abortions of spikelets at the tip of developing ears.

4.2.3 Seasonal Differences in the Position of the Shoot Apex

Figure 4.5; The height of the shoot apex of ungrazed (control) plants in relation to accumulated day degrees for all seasons.

Early April Sowing (1989 & 1990) **Late April Sowing (1988,1989 & 1990)**



The effect of season on the rate of development of the shoot apex can be seen in figure 4.5. The early sowing in 1989 and later sowings in all years commenced rapid stem elongation at about 1,000 day degrees. The early sowing in 1990 was delayed, probably due to dry conditions slowing emergence, as mentioned before. The actual rate of elongation did not vary greatly. It would be possible, using this data, to predict apex height from degree days and therefore use it as a guide for timing of grazing to avoid tip removal.

4.2.4 Available Forage

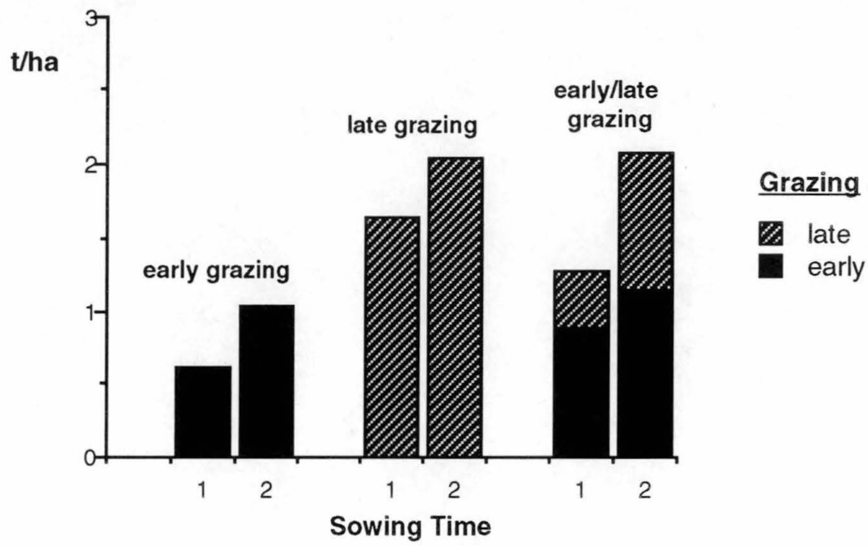


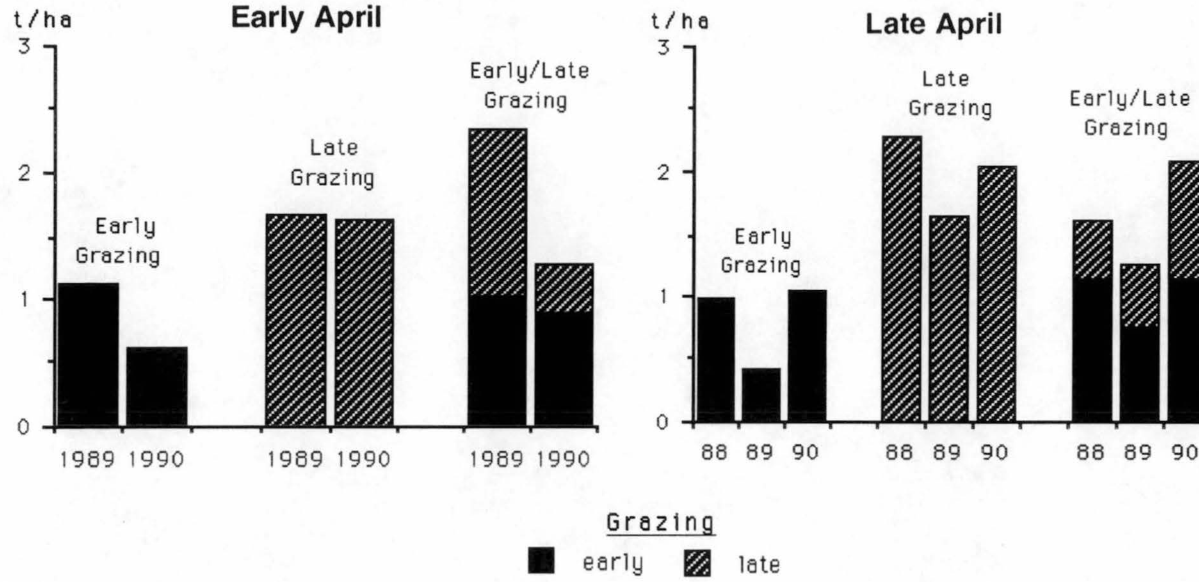
Figure 4.6; Forage removed by grazing for the early April sowing (1) and late April sowing (2) in the 1990/91 season.

The more rapid development in the late April sowing (fig. 4.3) is reflected in the greater amount of forage that was obtained at the first grazing in 1990 (fig. 4.6). Despite a similar number of days from sowing to grazing, more forage was harvested from the second sowing for all grazing treatments, due to the greater growth in the sowing.

However in comparing seasons (fig. 4.7) an overall trend is not obvious. Many variables including grazing height, crop growth rate and the time of grazing differed between seasons and affected the amount of forage harvested. The potential forage yield, without removing large numbers of growing points, seems to be limited to about 2.5 t/ha. With careful timing of grazing this potential could be realised by either a single late grazing or an early/late grazing.

Late April sowing generally gave at least as much forage as the earlier sown crops, but this was available some weeks later in each case, so the relative value of forage at different times in the winter and spring would need to be taken into account. The single early grazing, while only yielding about half as much forage as the other treatments in each case, could have been more valuable for livestock at that time.

Figure 4.7; A comparison of forage removed by all grazing treatments for both early and late April sowings for all seasons that the experiment was conducted.



4.2.5 Tiller number

In the early sowing tiller number per plant reached as high as 12 prior to the first grazing but then declined to 3 or 4 . On the late sowing tiller number reached up to 7, but the final number was similar to that of the early sowing, being 3 or 4 per plant. Tiller number did not seem to be increased following grazing, as may be expected by the removal of apical dominance, however not enough information was gathered for this observation to be conclusive.

Of more importance than the number of tillers is their ability to produce viable ears and carry them through to grain fill and harvest. This would be limited by the amount of assimilate available.

4.2.6 Crop growth

The change in plant dry matter during the period of grazing in 1990, for all treatments, is illustrated in figure 4.8. The dry weight of green leaf in the control hardly changed during this period. Grazing severely reduced leaf in all cases and recovery was generally poor, never reaching pre-grazing levels.

Stem dry weight increased rapidly, even following early grazing, which is to be expected as this was about the time that rapid stem elongation began. However following late grazing of both late and early/late treatments stem dry weight declined. There was little difference in actual growth rates between sowings during this period although the early sowing had a lower total dry matter.

Although change in plant dry matter was not recorded past the period of the second defoliation, some observations can be made. Following N application there was a noticeable difference in both growth and colour of the plus N plots of all treatments (plate 7.1). The plus N plots in each treatment became a darker shade of green and grew slightly longer than the nil N plots, which resulted in increased straw length at harvest (see sect. 4.2.8 page 77). In the previous seasons the effects of animal returns had not been obvious, however in this seasons trial there were noticeable improvements in growth in patches where dung or urine was left (plate 7.2).

The plus N plots tended to reach anthesis slightly earlier than nil N plots of the same treatment. and grazing delayed anthesis. Anthesis was observed in the plus N control of the first sowing in the last week of October, and in the plus N control of the second sowing three weeks later. The last treatment to reach anthesis was the late grazing of the late sowing.

Figure 4.8. Change in total dry matter during grazing 1990

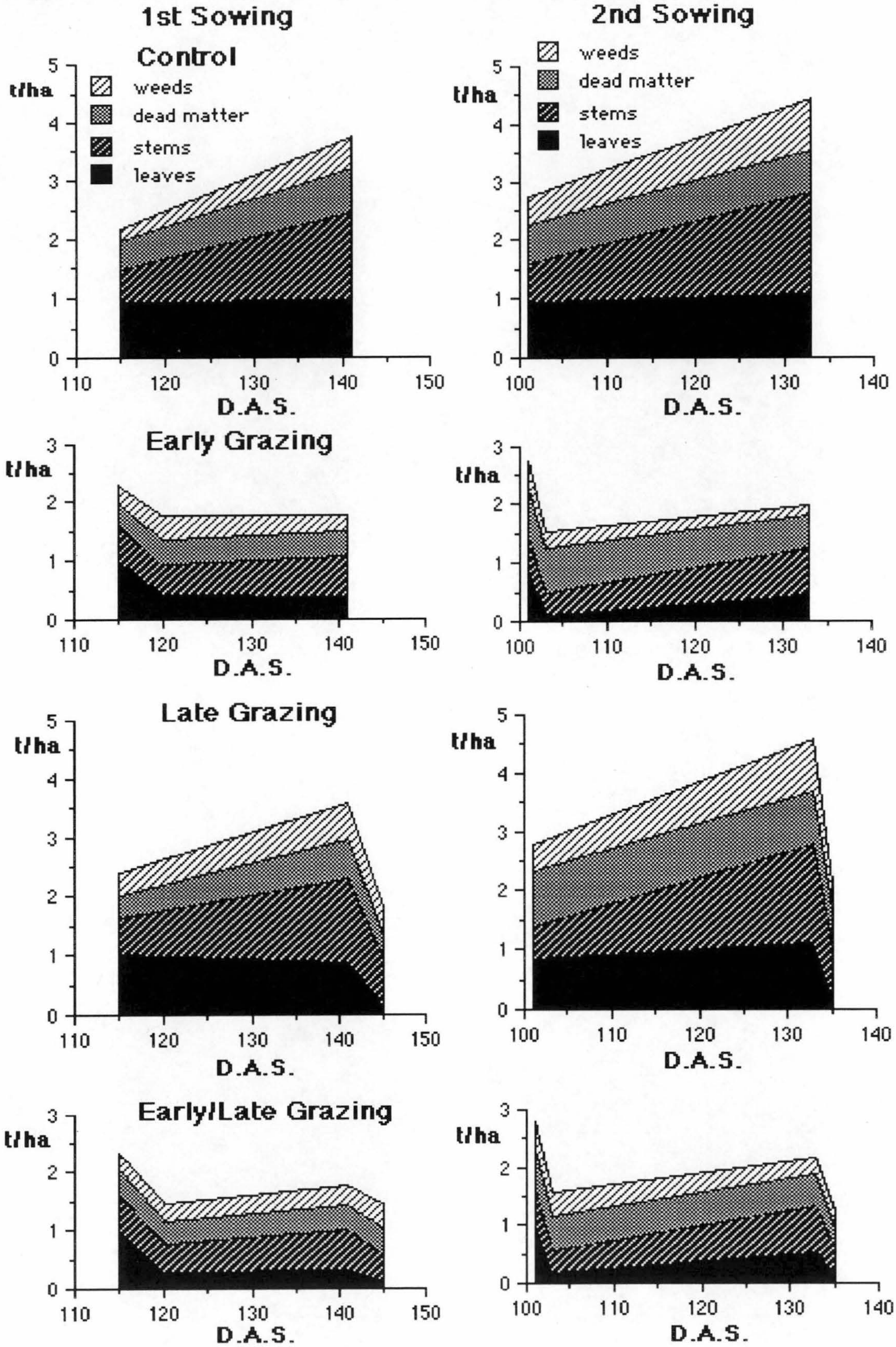


Plate 7.1 Differences in colour and height between nil N (left) and plus N (right) plots of the early grazing of the second sowing 23/10/90. The plus N plot is darker in colour and taller.

Plate 7.2 The effects of dung and urine patches, seen here in late October on the late grazing treatment of the first sowing, were an increase in growth and darker leaf colour.

4.2.7 Grain Yield

In the 1990/91 season the late sowing gave higher grain yields, particularly after grazing (fig. 4.9). In the previous year there had been a larger increase in yield in the control with later sowing, but little difference between sowings for the early grazed treatments.

N increased grain yield in all treatments, but only with the early grazing of the late April sowing did N fully compensate for the effects of grazing, bringing grain yield up to the level of the nil N control. While the grain yield penalty for late grazing was substantial, yields were still at commercially viable levels, particularly after N application.

Figure 4.9; Final grain yields for all treatments in the 1990/91 season. Bars indicating LSD's are for (a) sowing time, (b) grazing treatment, and (c) nitrogen treatment.

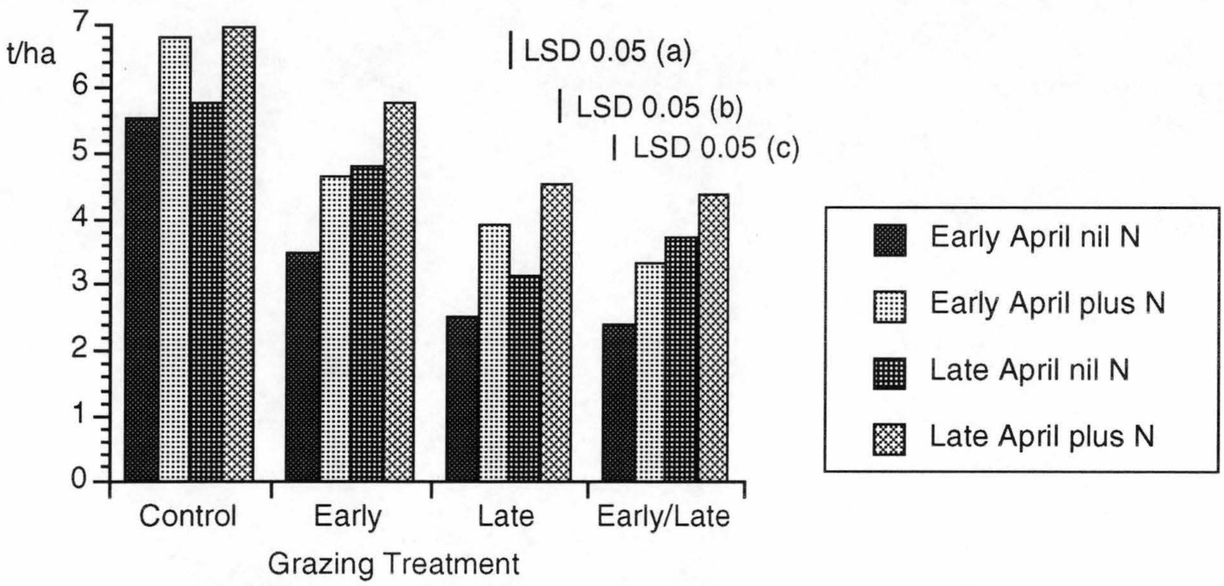
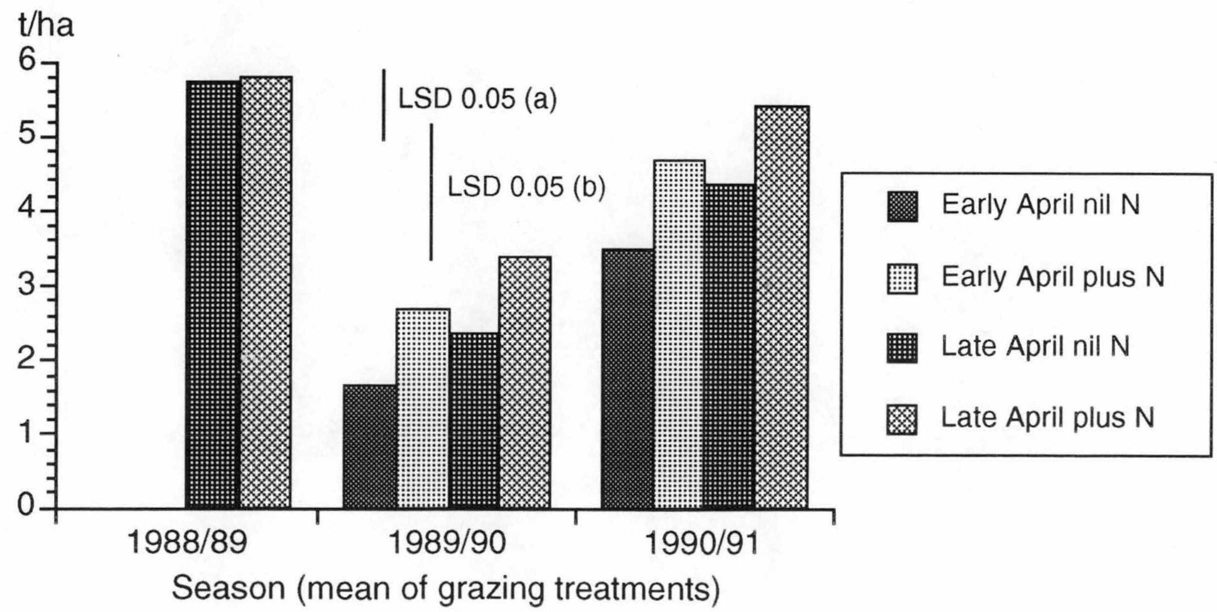


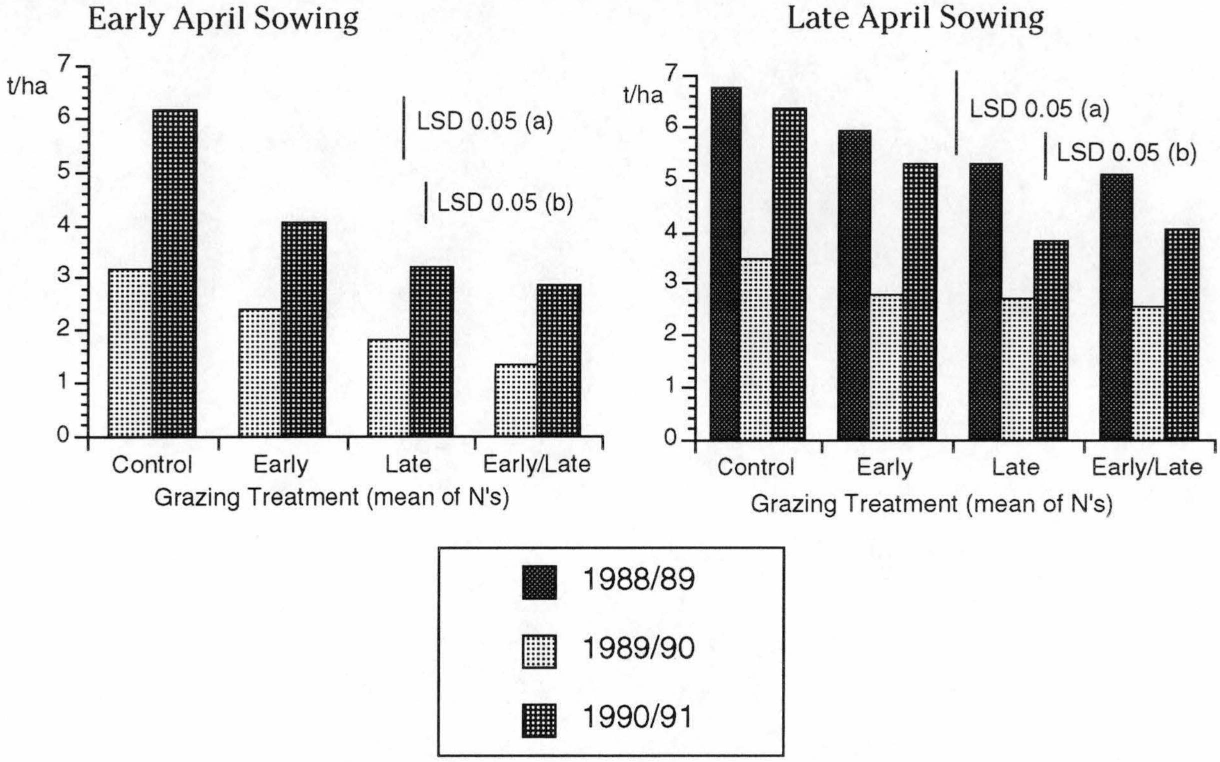
Figure 4.10; Grain Yield for all three seasons for both early and late April sowings. Bars indicate LSD 0.05 for season x N treatment for (a) early April sowing, and (b) late April Sowing



Taking mean grain yield of all grazing treatments and control, N had little or no effect in 1988/89, but increased yield in the other two seasons (fig. 4.10). Grain yields for all sowings in the 1989/90 season were well below those of the other seasons, due to the effects of waterlogging. Overall grain yields were increased with later sowing.

The effect of grazing treatment and season can be seen in figure 4.11, below. Grain yields for all treatments were reduced significantly at both sowing times in 1989/90, however trends remained the same. Overall it appears that increasing grazing pressure reduces grain yield regardless of the season.

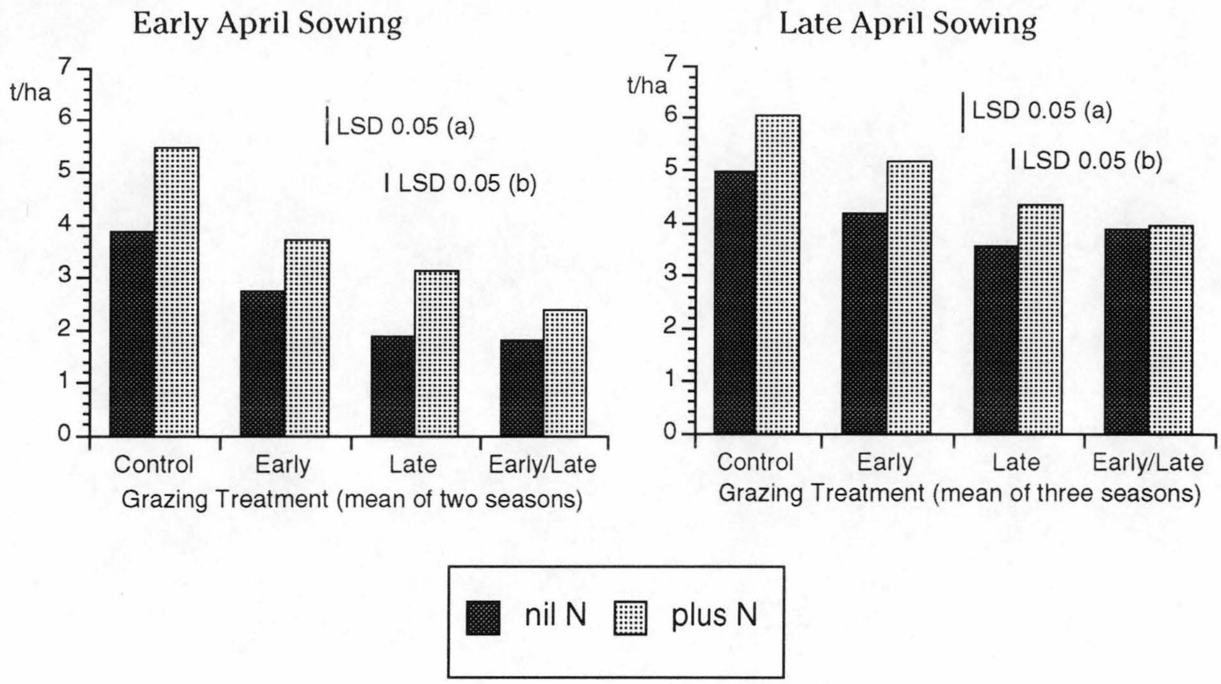
Figure 4.11; A comparison of grain yields in each growing season. Bars indicating LSD 0.05 are for (a) season, and (b) grazing treatment



If a mean of yields between seasons is taken the effect of grazing can be clearly seen (fig. 4.12). The trend at both sowing times was for a decrease in grain yield due to grazing, however N compensated for this and could return yields to the level of the nil N control if application followed a single early grazing.

The effects of both grazing and nitrogen were similar with either a single late grazing or early/late grazing.

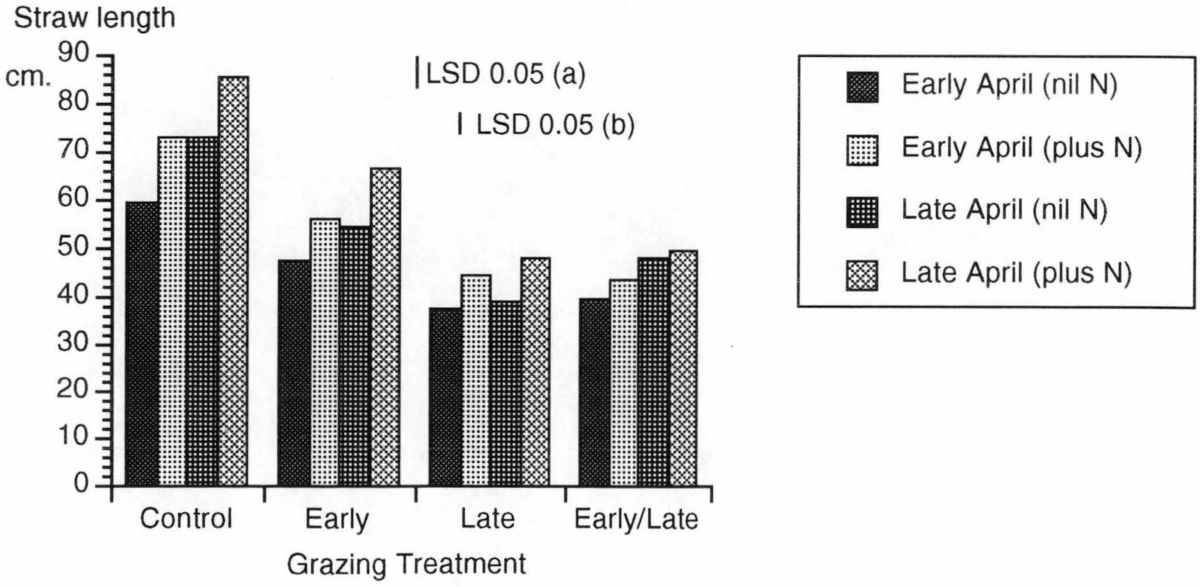
Figure 4.12; A comparison of grain yields with and without added N in all grazing treatments. Bars indicating LSD 0.05 are for (a) grazing treatment, and (b) N treatment.



4.2.8 Straw and Harvest Index

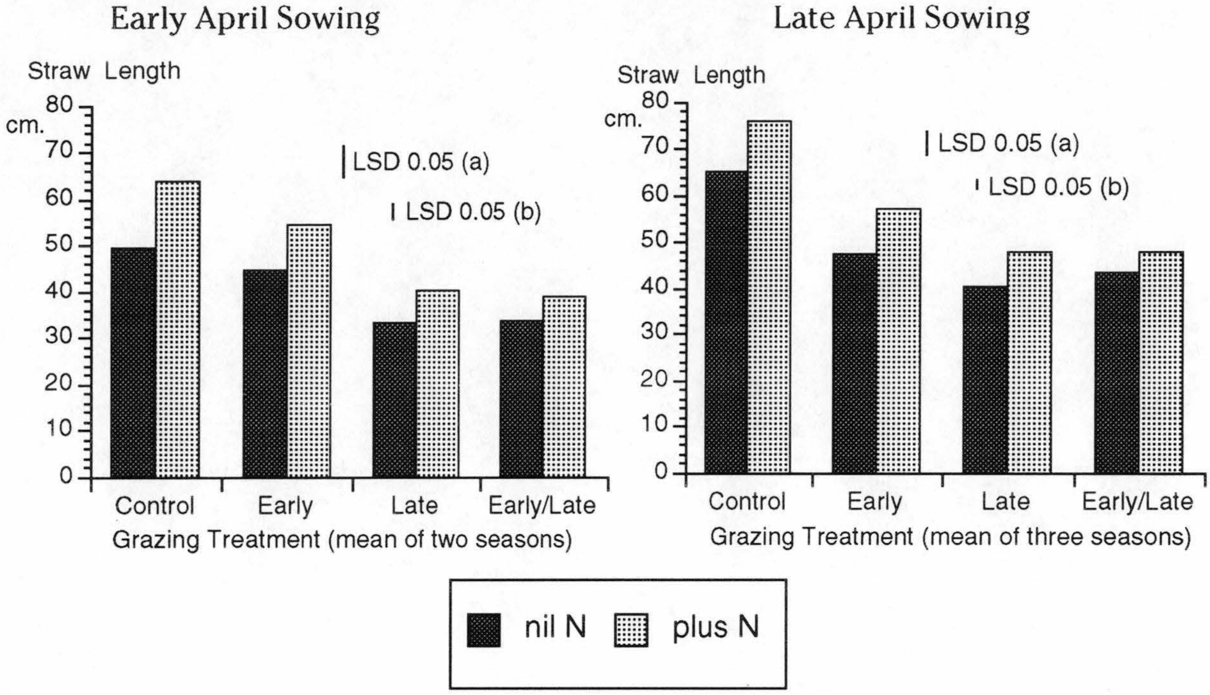
The trends in straw length in 1990 were similar to those in grain yield (fig. 4.13), with obvious differences between sowing times, grazing treatments and N treatments. The early April sowing produced less overall dry matter, and this is reflected in straw length.

Figure 4.13; Effect of sowing time, grazing treatment and nitrogen on straw length in the 1990/91 season. Bars indicating LSD 0.05 are for (a) grazing treatment, and (b) nitrogen treatment.



Looking at the average of all seasons (fig. 4.14) the decrease in straw length with increased grazing pressure is apparent. The compensatory effect of N can also be clearly seen. There is also a trend for straw length to increase with later sowing, however this was only slight in the previous season (see fig. 3.15, chapter 3).

Figure 4.14; Effect of grazing and N on straw length. Bars indicating LSD 0.05 are for (a) grazing treatment and (b) nitrogen application.



Waterlogging caused a reduction in straw length in 1989 (fig. 4.15), but trends were similar in each year.

Figure 4.15; Straw length on the late April sowing in all 3 seasons. Bars indicating LSD 0.05 are for (a) season and (b) grazing treatment.

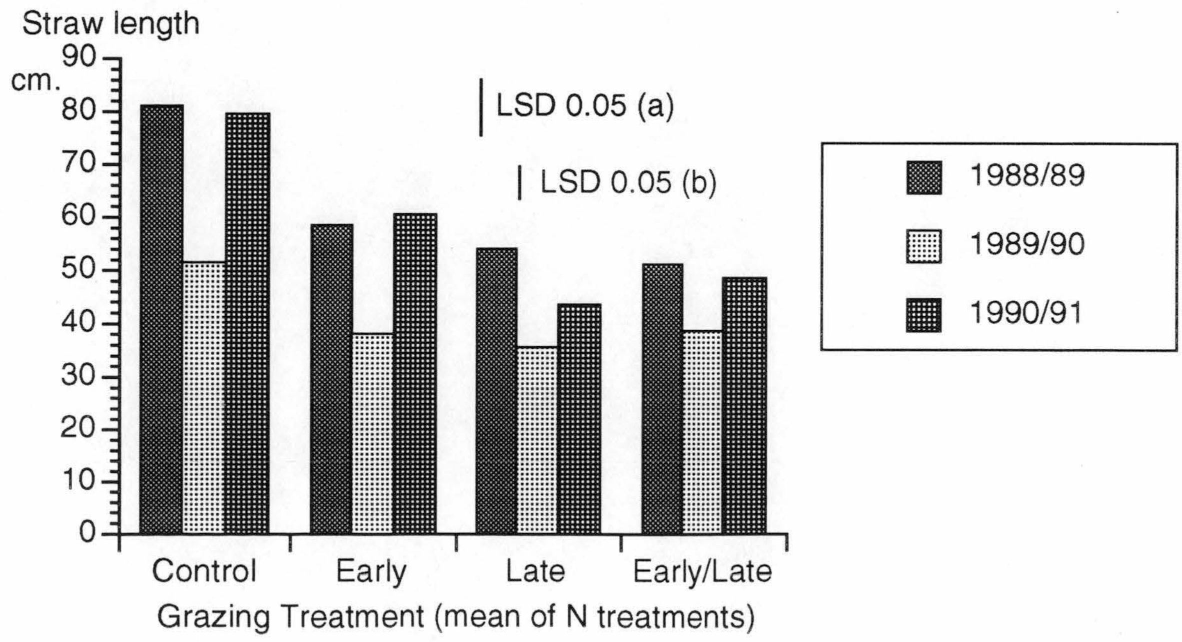
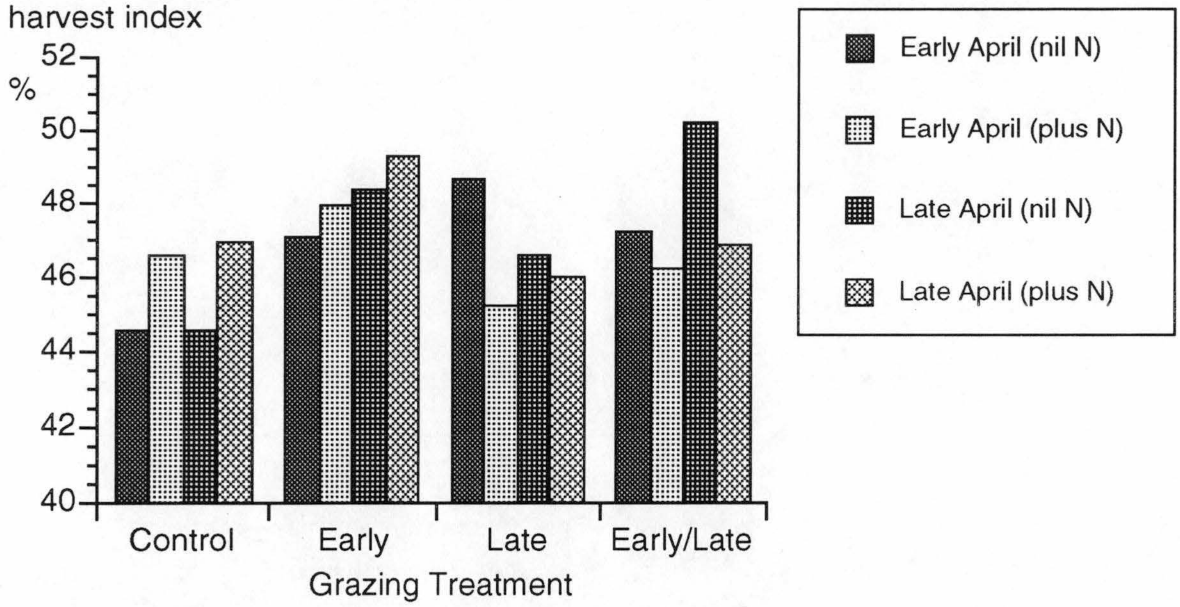
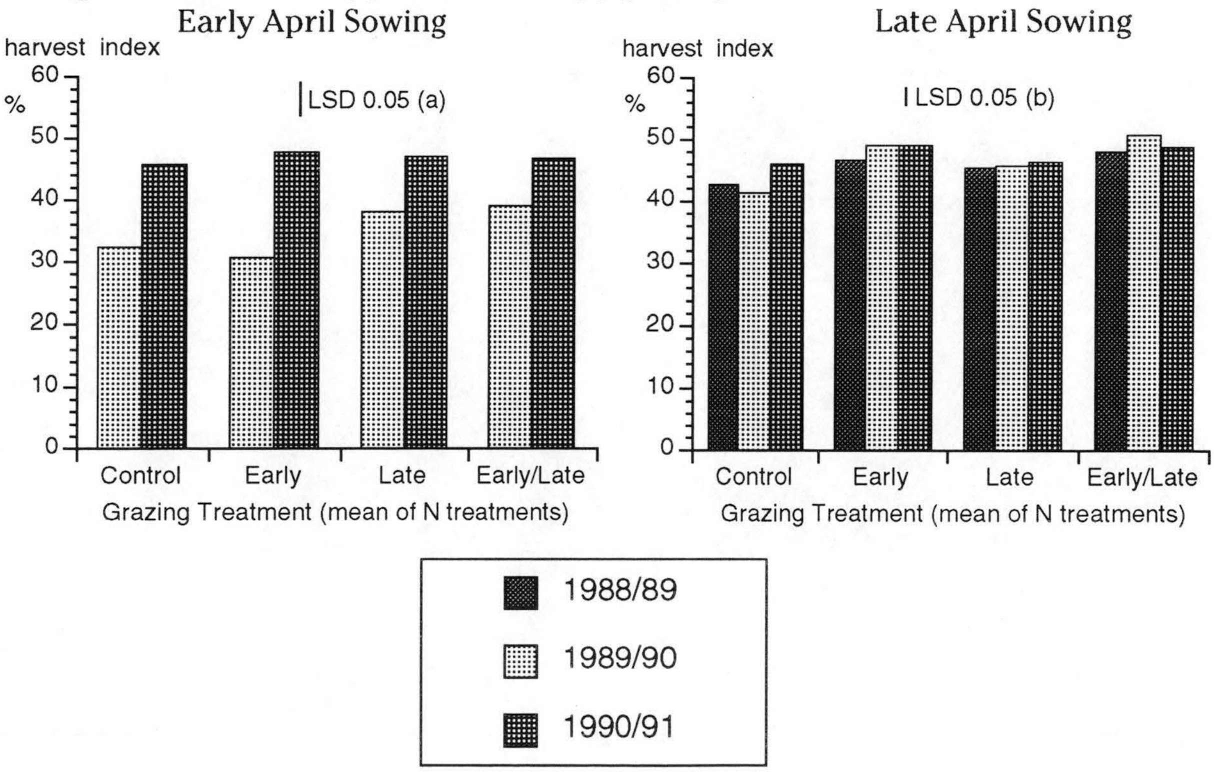


Figure 4.16; The effect of sowing time, grazing treatment and nitrogen on harvest index in the 1990/91 season.



In 1990/91, N increased harvest index in the control and early grazing treatments, and decreased it in the late and early/late treatments (fig. 4.16). This trend was not apparent in the previous (1989/90) season.

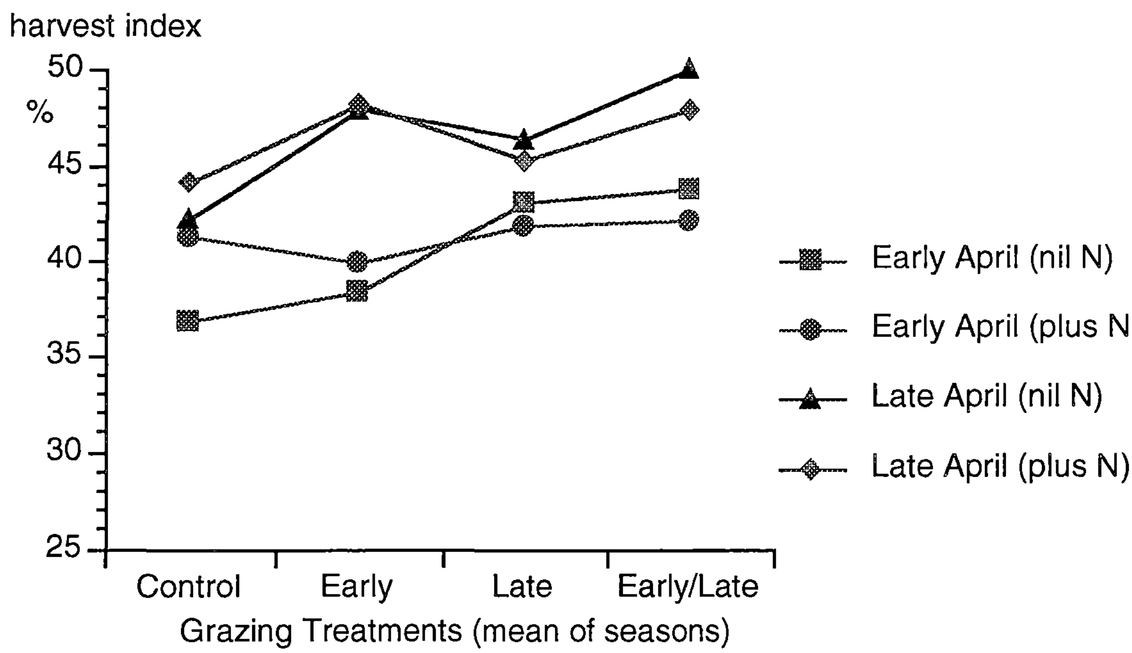
Figure 4.17; Effect of season and grazing treatment on harvest index. Bars indicating LSD 0.05 are for (a) season, and (b) grazing treatment



There was no significant difference in harvest index between seasons with the late April sowing, however with early April sowing it was significantly lower in the 1989/90 season (fig. 4.17). With both sowings the trend was for an increase in harvest index with grazing, although this was only statistically significant with the late April sowing.

The seasonal reduction in the early April sowing of 1989/90 was largely due to the effects of waterlogging. Substantial growth took place before waterlogging, but then subsequent development was restricted, grain number being reduced as a result of ear and spikelet abortion. However with the late April sowing of this season straw and grain yield were both proportionally reduced and as a consequence there was little difference in harvest index between it and the other seasons.

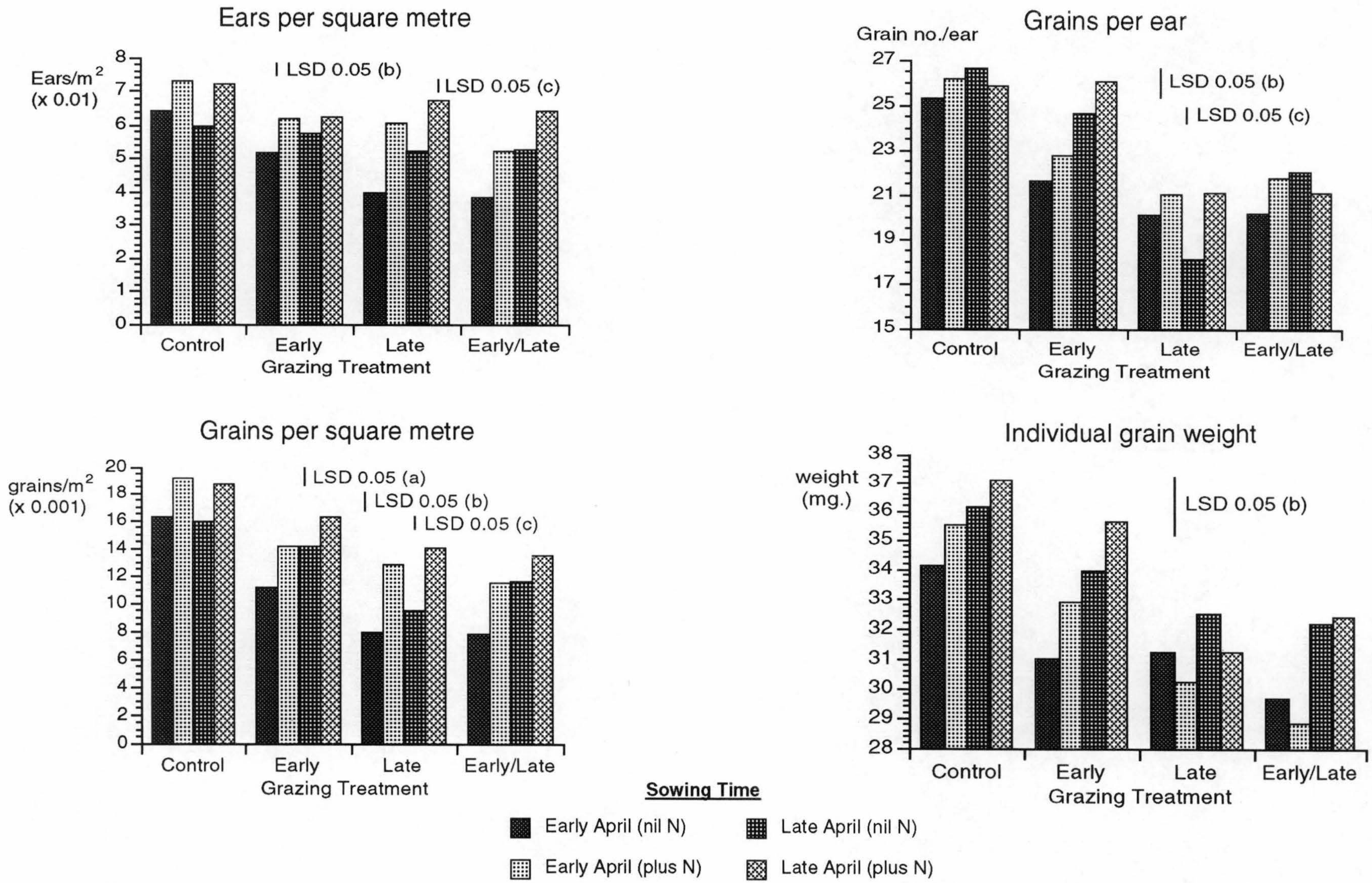
Figure 4.18; Effect of nitrogen and grazing treatment on harvest index for two sowing times 1990/91.



The overall trend with N was for an increase in harvest index in the control and early grazing treatments, and a decrease on the late and early/late grazing treatments for both sowing times. N therefore reduced the difference in HI between grazing treatments.

Grazing can therefore modify crop growth by reducing straw length and hence lodging, while also increasing harvest index. N tends to cancel these effects out.

Figure 4.19: The effect of grazing, N application, and sowing time on yield components in 1990/91.
Bars indicating LSD 0.05 are for (a) sowing time, (b) grazing treatment, and (c) N.



4.3 Components of Yield

4.3.1 1990/91 Season

The effect of grazing in this season was to reduce all components of yield (fig. 4.19). The trend was generally for the reduction to be greater with increased grazing pressure.

Yield components were generally greater in grazed treatments of the late than the early sowing. However, in the controls the difference between sowings was only apparent with grain number per ear, and individual grain weight. The exception in grazed treatments was in the number of grains per ear in the single late grazing treatment which was lower in the late sowing. An expected decrease in the number of ears, due to the large number of shoot apices removed (table 4.3) in this treatment, did not occur, so the crop must have compensated for the loss of the shoot apices by producing more tillers. These later formed and possibly weaker tillers then had fewer grain sites available. The higher individual grain weight however compensated in terms of grain yield, which was higher in the late sowing.

Nitrogen compensated for the effects of grazing by increasing the value of the components in most cases. The minor exceptions were the early/late grazing of the late April sowing, where N reduced grains/ear, and for individual grain weight where N decreased weight on the late and the early/late grazing treatments of the early April sowing. The reduction in individual grain weight due to N may have been due to an increase in grain number causing available assimilate to be spread more thinly among available grain sites during grain fill

While N was generally able to fully compensate for the reduction in ear number caused by grazing, it did not do so with grain number per ear. As a consequence grains per m^2 were lower following grazing even with an N application. It seems that N promotes tillering and enhances tiller survival, which increases ear number. However the extra ears are likely to be smaller and have fewer grain sites, therefore the average number of grains per ear is not greatly increased by N.

4.3.2 Seasonal differences

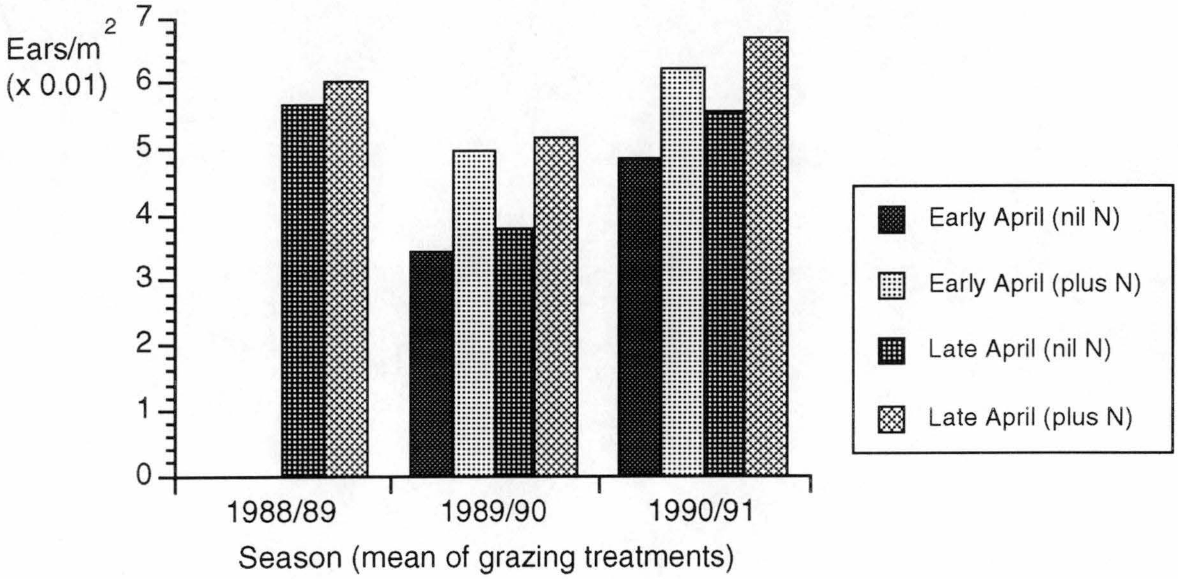
In looking at seasonal differences in the yield components (fig. 4.20) the obvious trend is the reduction in 1989/90 in comparison to the other seasons. The reduction occurred in all yield components in this season, resulting in the lower grain yields experienced. This is most likely the result of waterlogging which has been discussed previously.

The trend was for N to increase mainly number of ears and to a lesser extent grains per ear, and consequently the product of these, grains per square metre. N was more important in increasing ear number, perhaps due to encouraging tillering. Due to the combined effect on ear number and grains per ear, grain number per square metre was higher with late sowing in both 1989/90 and 1990/91, although N generally compensated for this.

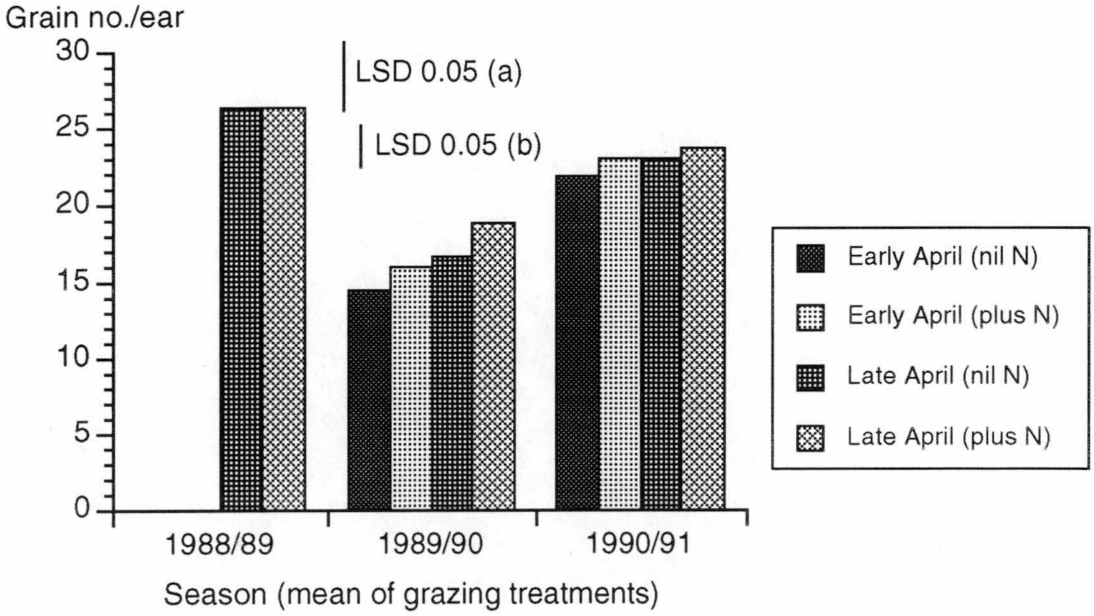
The seasonal trend was somewhat different with individual grain weight, which was significantly higher in 1988/89 than the other two seasons. This may in part be due to the fertility of the site chosen as in 1988/89 the site had not been previously cropped and had a long history as pasture while the sites chosen in the subsequent seasons had previously had nitrogen hungry crops such as onions. Again the trend was for an increase with late sowing although this was distorted by the effects of N on the late sowing in 1989/90 which decreased individual grain weight.

Figure 4.20; The effect of season and nitrogen application on components of grain yield. Bars indicating LSD0.05 are for (a) season and (b) nitrogen treatment.

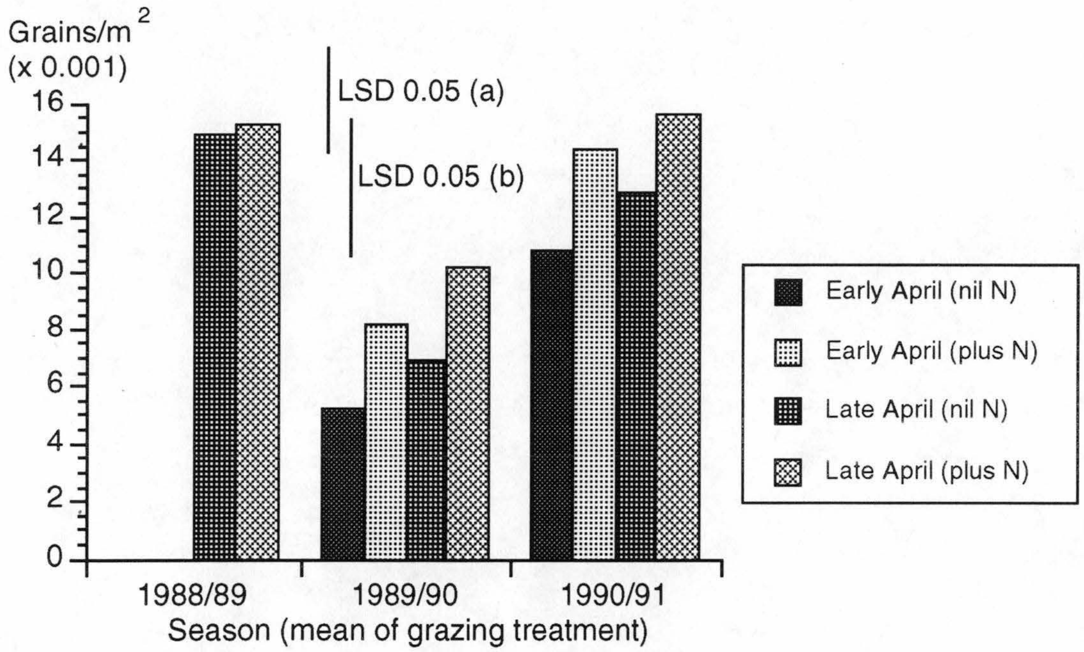
4.20.1 Ears per square metre



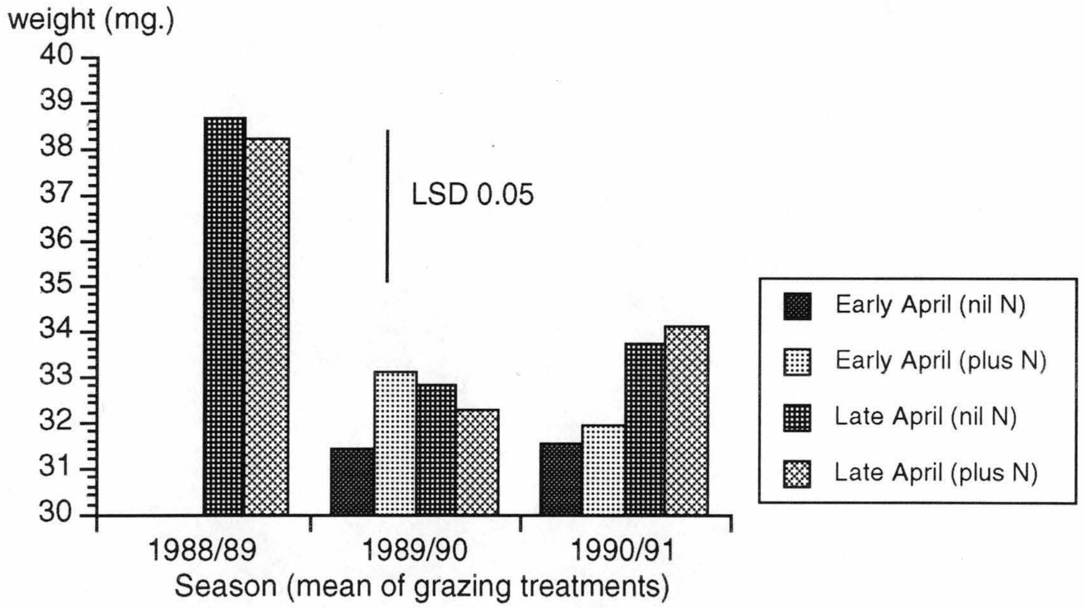
4.20.2 Grain number per Ear



4.20.3 Grains per square metre



4.20.4 Individual grain weight (LSD shown is for between seasons).



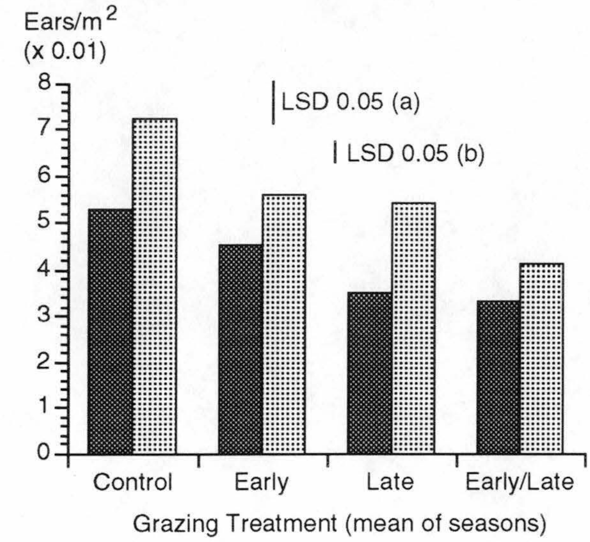
4.3.3 Overall Trends in the Effects of Grazing

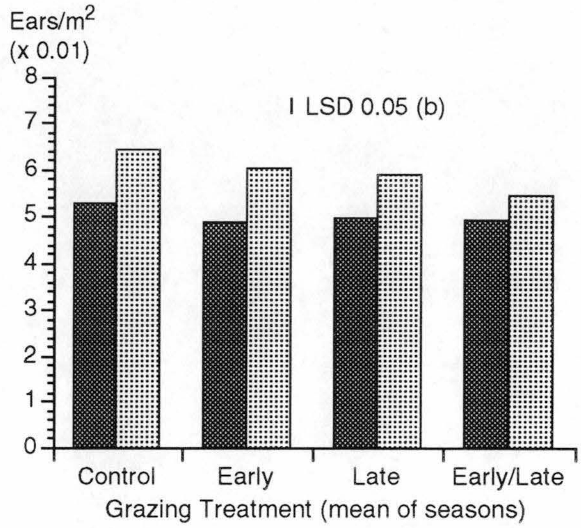
By taking the mean of seasons the effect of grazing on the components of yield can be seen (figure 4.21).

Figure 4.21; The effect of grazing on the components of grain yield, averaged over all seasons for two sowing times. Bars indicating LSD 0.05 are for (a) between grazing treatments, and (b) between N treatments.

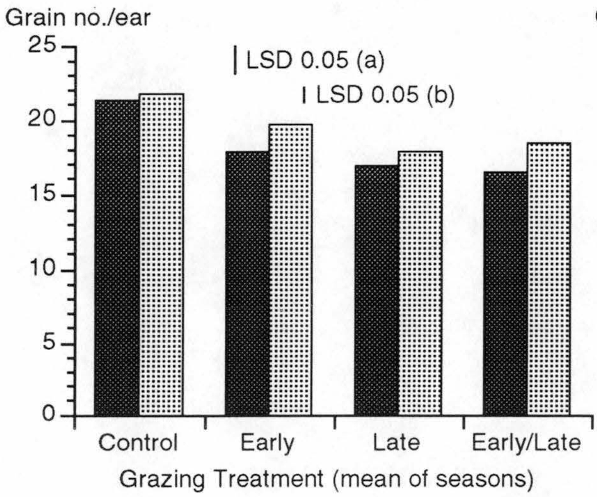
Early April Sowing (mean of two seasons) | **Late April Sowing** (mean of three seasons)

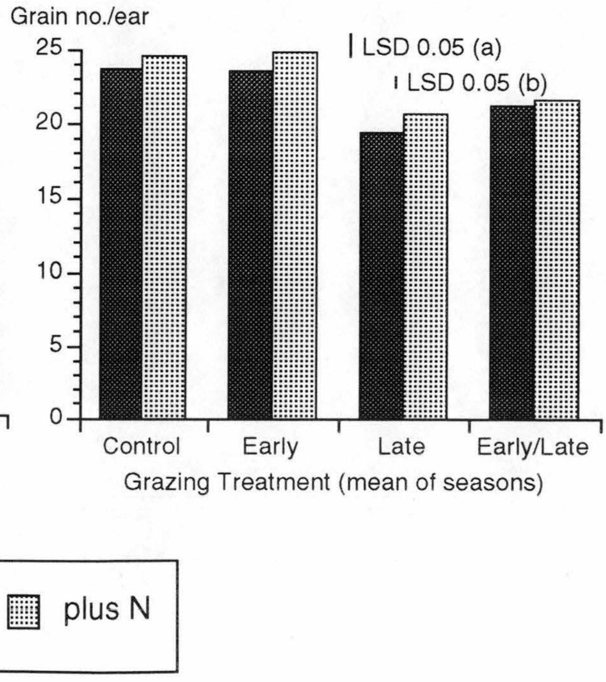
4.21.1 Ears per square metre



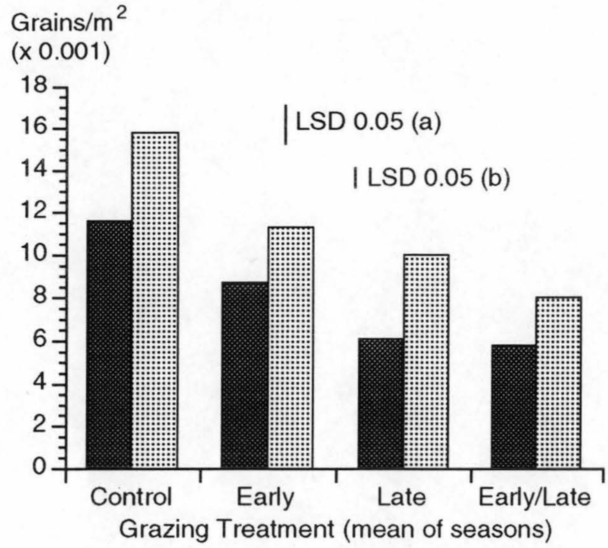


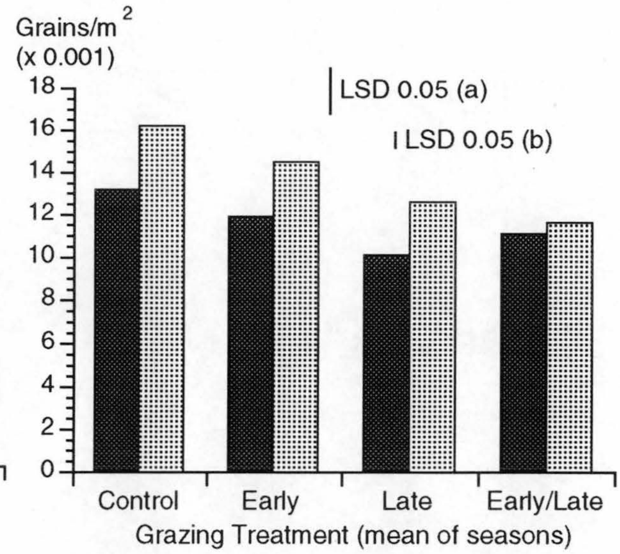
4.21.2 Grains per Ear





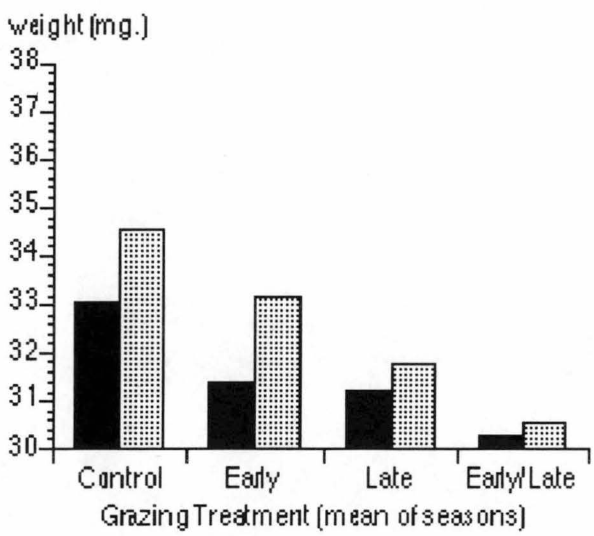
4.21.3 Grains per Square metre



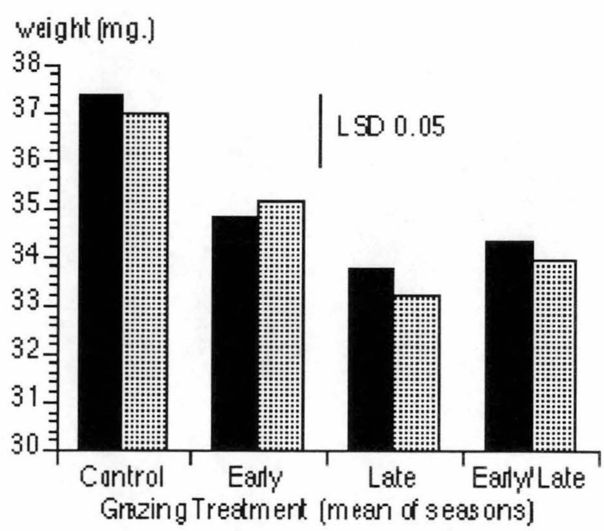


4.21.4 Individual grain weight (LSD shown is for between grazing treatments).

Early April sowing



Late April sowing



The overall trends due to grazing in each season have generally been consistent. As grazing pressure increased, the yield components were reduced. N caused a large increase in grains per square metre largely by increasing ear number although it also caused a small increase in grains per ear at each treatment level. A decrease in ear number due to grazing is more apparent in the early April sowing although it must be remembered that this is the average of two seasons, while the results for the late April sowing includes 3 seasons. Overall there was a steady decline in ear number with increased grazing pressure.

Grains per ear were reduced by all grazing treatments with the early April sowing but only the late and early/late treatments with the late April sowing. Growth conditions when the early grazing of the late sowing was recovering must have been sufficient to develop most of the grain sites available. Late grazing of the late April sowing reduced grains per ear more than early/late grazing and this is reflected in grain number per square metre. This trend can also be seen with grain yield (fig. 4.13), and individual grain weight (fig. 4.21.3).

With grain number per square metre there was a steady decline with increased grazing. Nitrogen tended to fully compensate for the effects of grazing on grain number per square metre but this is largely due to its effect on ear number as it failed to fully compensate for a reduction in grains/ear caused by all grazing treatments.

The reduction in individual grain weight with increased grazing reflects the amount of assimilate available for grain fill following grazing. This relates to the reduction in L caused by grazing. N was effective in increasing individual grain weight with the earlier sowing but generally caused a decrease with the later sowing time.

CHAPTER FIVE

AN ECONOMIC COMPARISON OF A DUAL-PURPOSE AND A PURE GRAIN CROP

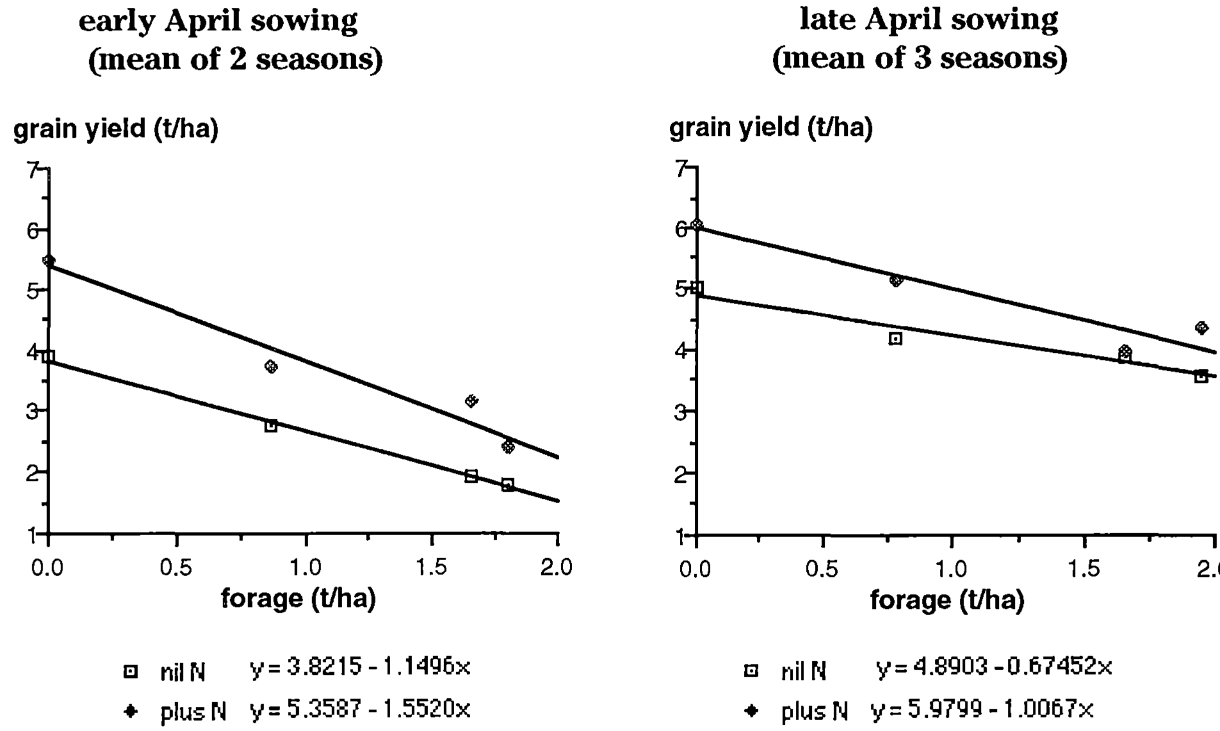
Although it is possible to obtain grain yields from grazed crops close to those of ungrazed crops it is obvious that there is generally a grain yield penalty following grazing. The question is whether the value of the forage offsets the reduction in grain yield. Several workers when looking at cereals as dual-purpose crops, have conducted economic analyses of those crops. Dann et al (1983) concluded that grazing wheat can be more profitable than a pure grain crop, but that this will depend on the relative prices of meat, grain and hay. More recently Yau et al (1989b) found that grazing barley increased net revenue on average in northern Syria. There is a need, however, for similar analyses to be done for Tasmanian conditions.

5.1 Forage versus Grazing

Dann et al (1977) looking at the effects of winter grazing on a range of crops including barley (cv. Abyssinian), compared final grain yield to forage removed as a means of assessing the cost of grazing. Dann (1968), when looking at the effect of clipping on the yield of wheat, calculated a regression equation relating grain yield to herbage removed as $y = 2558 - 0.7x$, where y = grain yield (lb per acre) and x = herbage removed at clipping (lb per acre). This implies the production of 0.5 starch equivalents per pound of herbage at a cost of about 0.5 equivalents per pound of grain. It was thought appropriate to do a similar exercise to these with this experiment (figure 5.1).

The trends are similar to those observed by Dann et al, however they had forage yields above 4 tonne/ha. Although the good results obtained in 1988 altered the mean of the late April sowing in figure 5.1, the trend for the slope of the regression line to be lower reflects what occurred in each growing season. At similar forage yields, grain yield is likely to be higher in the late April sowing for this cultivar.

Figure 5.1; A comparison of grain yield with forage removed Comparing both the early April and late April sowings at both rates of N, and showing lines of best fit and equations where x = forage removed (t/ha) and y = grain yield (t/ha).



5.2 Energy Budget

The Victorian Department of Agriculture has published estimates of the energy composition of various feeds (Smith, 1983). Barley forage is given as having 9 MJ/kg dry matter of metabolisable energy and barley grain as having 13 MJ/kg dry matter. On this basis the energy available from both forage and grain as a feedstuff was assessed (table 5.1).

Generally where a trend was obvious total metabolisable energy (ME) decreased with increased grazing. However in 1989 no clear trends emerged and in 1988 there was an increase in ME with increased grazing on the nil N treatment. The 1988 result is due to the small decline in grain yields with increased grazing compared to the large increase in forage yields, which occurred on the nil N treatment. Poor grain yields and reduced forage production following waterlogging caused the lower ME's in 1989. Nitrogen in most cases increased ME due to increased grain yields.

Table 5.1; Total Metabolisable Energy (MJ/ha x 10^{-3}) harvested (forage plus grain) for all experimental treatments.

		Sowing Time					
			nil N			plus N	
		late March	early April	late April	late March	early April	late April
1988							
	control			81.64			93.6
	early			80.25			90
	late			87.3			90.03
	early/late			92.01			71.86
1989							
	control	18.59	28.34	37.7	23.27	54.08	52.65
	early	10.93	35.69	32.33	13.01	46.35	47.15
	late	31.54	31.97	45.14	34.27	45.49	54.5
	early/late	19.74	36.92	36.99	23.77	40.3	52.2
1990							
	control		72.28	74.88		88.27	90.22
	early		50.86	71.93		66.07	84.67
	late		47.17	58.83		65.5	77.16
	early/late		42.54	66.53		54.63	74.85
Mean of all Seasons	control		50.31	64.74		71.24	78.78
	early		43.32	61.49		56.19	73.97
	late		39.68	63.83		55.54	73.97
	early/late		39.73	65.25		47.4	66.29

5.3 Economic Analysis

Any economic comparison of the value of both forage and grain yield is affected by a number of variables other than those previously discussed (such as season, management and nitrogen application). These include the forage intake of each animal, its daily weight gain, current market price of the animal, the market price of the grain, and the variable costs involved in growing the crop.

The heifers used for grazing in 1990 had a mean liveweight of 300kg at the conclusion of grazing in mid-September and the average weight gain up to that period had been 1kg per day. Assuming that they had a mean liveweight of 250kg during grazing, and that they ate dry matter equal to 2.5% of their liveweight each day (Smith, 1980, Victorian Department of Agriculture), they would have consumed 6.25kg of dry matter to produce 1kg of liveweight gain, at an assumed $1.17 per Kg.

These figures could have been altered by a number of factors, for instance depending on the genotype of the heifers used weight gain per day could have varied between 0.5 and 1.0 kg/day. Dry matter intake per animal per day will rise as the animal gets older and heavier, for instance a 500Kg animal with a growth rate of 1.0kg/day will consume 10.7 kg of dry matter (Smith, 1980) per day.

Return for the grain produced is based on the current price for feed barley which is $140/tonne. Feed barley price was used as Ulandra being a winter barley is not considered to be of malting quality. To gain an idea of the calculations involved an example of a gross margin budget is given below for a 5 tonne/ha pure grain crop. This gross margin budget is based on the malting barley budget in the North-West Coast Cash Crop Enterprise Budgets for 1990-91, produced by the Tasmanian Department of Primary Industry.

Table 5.2 Gross margin budget for Ulandra barley in north-west Tasmania

			$/ha
GROSS INCOME			
Yield		5.00 t/ha	
Price		$140.00 /tonne	$700.00
Total Gross Income			$700.00
VARIABLE COSTS			
Materials			
seed		110 kg/ha at $400.00 /t	$44.00
fertilizer		300 kg/ha at $233.70 /t (applied with seed)	$70.11
weed control			
MCPA-250	(1 spray)	2.5 L/ha at $3.64 /L	$9.10
Banvel-200	(1 spray)	0.7 L/ha at $14.60 /L	$10.22
pest control			
Lorsban	(1 spray)	0.8 L/ha at $21.80 /L	$17.44
nitrogen			
sulphate of ammonia		250 kg/ha at $298.95 /t	$74.74
Tractor and Plant			
land preparation		4.50 hr/ha at $10.13 /hr	$45.59
drilling		1.00 hr/ha at $10.13 /hr	$10.13
top dressing		0.60 hr/ha at $7.35 /hr	$4.41
weed control		0.60 hr/ha at $7.35 /hr	$4.41
Contract			
pest control (aerial spraying)		(1 spray) at $30.00 /ha	$30.00
harvesting		$20.00 /t	$100.00
cartage		$10.00 /t	$50.00
Total Variable Costs			$470.14
GROSS MARGIN			$229.86

In table 5.2 above, variable costs changed with nil or added N, and harvesting and cartage costs varied with grain yield. By adjusting variable costs for grain yield and N application and using the returns for forage and grain previously mentioned the following table (table 5.3) was produced. The values in brackets represent losses.

Table 5.3; Estimated return (Gross margin $/ha) from the various treatments for each season and sowing time.

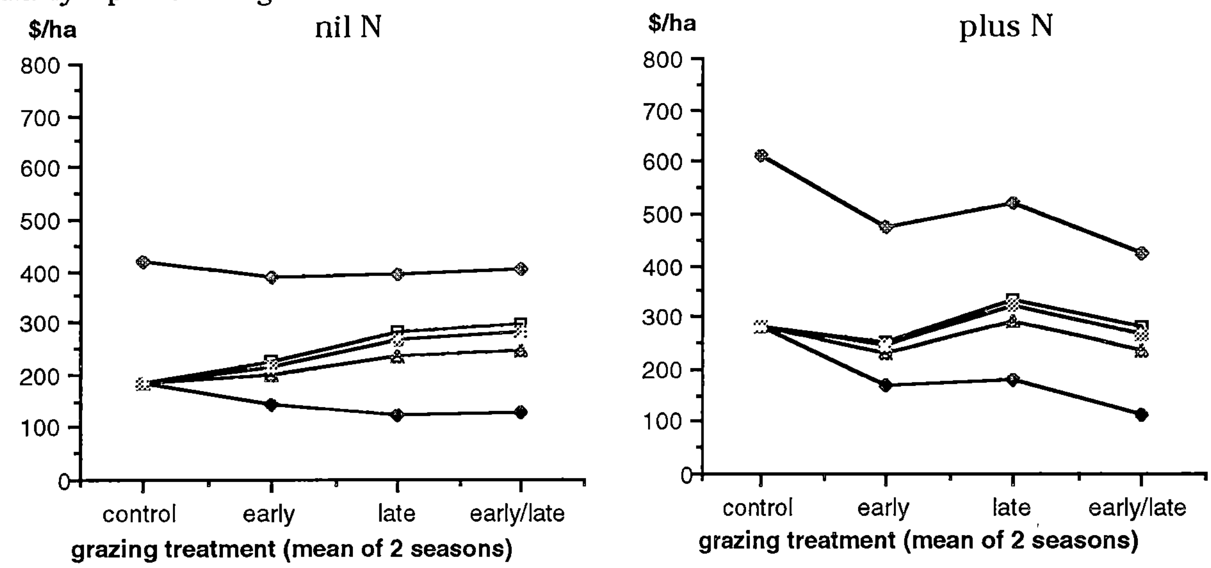
		Sowing Time					
		nil N			plus N		
		late March	early April	late April	late March	early April	late April
1988							
	control			$449.80			$471.86
	early			$537.98			$541.34
	late			$737.55			$681.51
	early/late			$729.66			$480.02
1989							
	control	($83.70)	($1.20)	$78.00	($123.24)	$137.46	$125.36
	early	($87.44)	$185.36	$76.98	($148.98)	$196.42	$123.24
	late	$240.20	$213.85	$324 18	$184.16	$249.11	$324.24
	early/late	$34.86	$331.25	$210.80	($10.18)	$280.71	$260.36
1990							
	control		$370.60	$392.60		$426.76	$443.26
	early		$257.09	$482.02		$306.65	$510.68
	late		$339.14	$482.22		$415.10	$558.18
	early/late		$258.87	$542.93		$282.03	$534.19
Mean of all Seasons	control		$184.70	$306.80		$282.66	$346.46
	early		$222.16	$365.92		$251.92	$392.38
	late		$277.98	$515.64		$333.04	$522.30
	early/late		$295.06	$495.45		$280.82	$425.11

The general trend was for an increase in income per hectare for the grazing treatments. In the 1989 season when waterlogging affected the crop returns were poor for all treatments, but grazing greatly increased returns. On average the later sowing had the highest return at each treatment, however this was subject to some variation between seasons. Nitrogen application generally gave similar returns for all treatments except early/late grazing where it was less profitable. The late March sowing was extremely unprofitable in 1989 and would perhaps have been better resown after grazing, with a spring barley crop for grain.

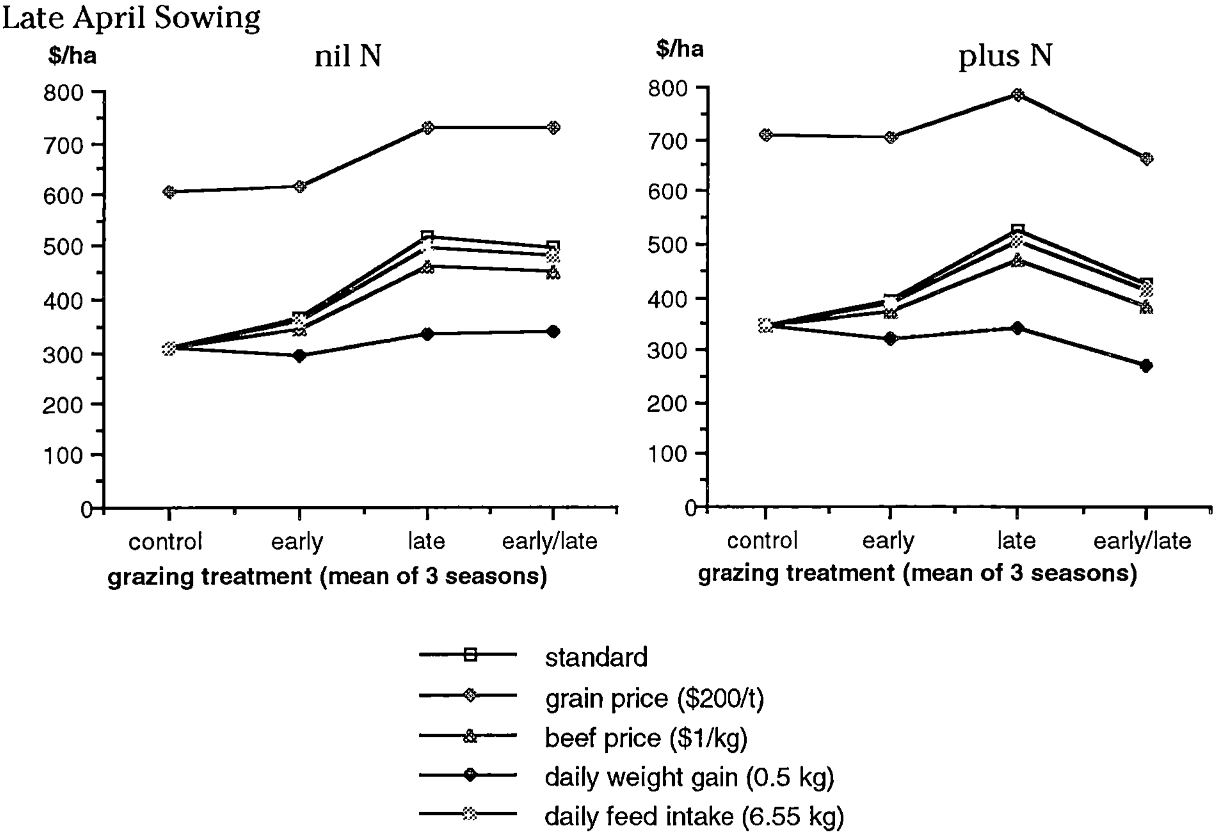
As well as seasonal differences beef and grain prices, forage intake and weight gain can vary. The following graphs (fig. 5.2) show the effect of changing any of these variables at the two April sowing times for both nil and added N using mean grain and forage yields for all seasons. The cost of 50kg/ha of N (250kg/ha of sulphate of ammonia) is included in the plus N figures. The changes from the standard values shown are an increase in grain price to $200/tonne, an decrease in beef price to $1/kilogram, a decrease in daily weight gain per animal to 0.5 kg/day, and an increase in daily feed intake per animal to 6.55 kg/day.

Figure 5.2; The effect on return ($/ha) of changing individual variables.

Early April Sowing



Late April Sowing



An increase in grain price or a decrease in daily weight gain are the factors that have the greatest effect in altering the relative profitability of grazing as opposed to a pure grain crop. However even considering any of these factors in isolation grazing remains more profitable at the late April sowing.

In the late April sowing late grazing appears the most profitable. However at this stage the nutritional value of the forage may be less than at the early grazing, and therefore the overall value of the dry matter may possibly be less.

5.4 Conclusion

Grazing offered an economic boost in all seasons and therefore appears to have an advantage over a pure grain crop. However an increase in the price of grain would diminish and possibly remove this advantage. Nitrogen while boosting grain production was generally of little economic benefit, a factor which has been shown before with other dual-purpose cereals (Dann et al, 1983). At current grain prices, it would only increase financial return marginally in most cases. Higher grain prices and either early grazing or no grazing would give the largest benefits from N. In future it may be worth examining the effects of an earlier N application, or a split application (before and after grazing), as this may increase forage production as well as grain production.

Ralph (1984) reviewing several previous experiments, concluded that there were no discernible differences between sheep and cattle in the effects on grain yield of a dual-purpose crop. It would therefore be possible to do a similar economic analysis for grazing sheep. It is obvious that a dual-purpose crop will give a farmer increased flexibility. The decision whether to graze can be based on current grain and meat prices.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

While varying slightly between the three seasons the weather followed a general pattern that is typical for the north West Coast of Tasmania. Rainfall reached a peak during the winter months, following an Autumn break. The break occurred in April in 1989, May in 1988, but not till June/July in 1990. However in all seasons the pattern of change in mean monthly temperature was the same, with the winter months (June, July, and August) being the times of lowest temperature and little growth. These months are when extra feed is needed to cover gaps. The weather pattern is generally similar for all the major farming areas in the state.

For a crop to be useful as a winter forage crop it would need to be sown between February and late April to allow time for sufficient dry matter to be produced before the cold weather slows growth.

Grain crops have traditionally been sown in the spring and harvested in January/February. More recently winter grain crops have been sown in May or June for harvesting in January. A dual purpose crop would need to be sown earlier for sufficient forage to accumulate by the time it would be most needed, that is from mid June through to mid September.

6.1 Recommendations

On the basis of the results obtained from the experiments it is apparent that the most suitable sowing times for a dual purpose barley crop are in April. If sown earlier than this grain yields are unsatisfactory and it would therefore be better to resow a grain only barley cultivar in the Spring. On this basis it may therefore be preferable to sow a higher yielding forage such as oats if a March sowing time is necessary, and then follow this with a pure grain crop in Spring.

The method of grazing used during the experiments would be most closely resembled by either a rotational or a block grazing system. Block grazing is gaining popularity in the North West Coast of Tasmania as a system which maximises utilisation of available feed. It is therefore likely that the results from the experiments could be directly applied to grazing systems employed in this area.

If forage is needed in early winter a pure forage crop sown in March would be the best choice, if forage is needed in mid winter an early April sowing would be the best, while late winter and early spring would be best covered by a late April sowing.

If the main concern of a farmer is grain yield then an early grazing as soon as there is sufficient forage is the best. However if forage yield is more important then either a single late or an early/late grazing would be suitable, although the early /late grazing would spread the times of forage availability.

6.2 Areas for future research

It has been established by this project that grazing can be successful, however the results are more generally applicable to block grazing than the more widely practised prolonged grazing. Prolonged grazing is still the most common and practical form of grazing in other areas of the state. However the general principles in relation to sowing time and ceasing grazing before the shoot apex reaches grazing height are still relevant.

Further work will be needed using prolonged grazing instead of crash grazing to determine how it would effect crop growth and grain yield. It may be expected that as long as some residual leaf area remains there would still be the possibility of a reasonable grain yield.

Another possible area for examination would be the effect of later sowing times such as early to mid May, as these would possibly provide grazing in late September.

The application of N to assist recovery is also worth further investigation. Although it was shown that N application could increase grain yield, under present circumstances it is uneconomic. However different methods of application such as a split application may be more useful.

Finally one factor not examined but suitable for use in North West Tasmania is the use of irrigation in Spring to increase grain yield. The effect of irrigation possibly in combination with N application would be an area well worth further investigation.

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APPENDIX A

Grain dry weight 1988/89

		B1	no N			
		B2	plus N			
BLOCK-1		B3	clipping			
	control	early	late	early/late	total	ΣY^2
B1	6.52	7.67	6.28	5.78	26.25	174.19
B2	7.11	7.62	6.22	4.26	25.21	165.45
B3	6.52	5.69	3.23	3.14	18.58	95.18
total	20.15	20.98	15.73	13.18	70.04	1267.33

BLOCK-2	control	early	late	early/late	total	
B1	6.38	2.50	5.16	4.22	18.26	91.39
B2	7.07	4.51	6.02	3.47	21.07	118.61
B3	6.38	2.94	4.26	1.97	15.55	71.38
total	19.83	9.95	15.44	9.66	54.88	823.94

BLOCK-3	control	early	late	early/late	total	
B1	5.95	6.48	4.22	7.64	24.29	153.57
B2	7.41	6.76	4.06	5.26	23.49	144.76
B3	5.95	7.77	3.94	2.89	20.55	119.65
total	19.31	21.01	12.22	15.79	68.33	1212.95

SUMS					TOTAL	ΣY^2
total b1	control B1	early B1	late B1	e/l B1	193.25	1134.17
68.80	18.85	16.65	15.66	17.64		ΣY^2ij
total b2	control B2	early B2	late B2	e/l B2		3304.22
69.77	21.59	18.89	16.30	12.99		
total b3	control B3	early B3	late B3	e/l B3		
54.68	18.85	16.40	11.43	8.00		
	control	early	late	e/l		
	59.29	51.94	43.39	38.63		

r(blocks)	a (treatments)	b (subtreats.)
3	4	3

correction term	1037.38
SS(total)	96.79
SS(whole units)	64.03
SS(blocks)	11.49
SS(A)	27.96
SS(B)	11.89
SS(AB)	11.20
SS Error(b)	9.68

Source	df	SS	MS	F
Blocks	2	11.49	5.75	
A	3	27.96	9.32	2.28
Error(A)	6	24.58	4.10	
whole unit Total	11	64.03	5.82	
B	2	11.89	5.94	9.83***
AB	6	11.20	1.87	3.09**
Error(B)	16	9.68	0.60	
subtotal		32.76		
TOTAL		96.79		

TREATMENT MEANS				SUB-TREATS
control B1	early B1	late B1	early/late B1	B1
6.28	5.55	5.22	5.88	5.73
control B2	early B2	late B2	early/late B2	B2
7.20	6.30	5.43	4.33	5.81
control B3	early B3	late B3	early/late B3	B3
6.28	5.47	3.81	2.67	4.56
control	early	late	early/late	
6.59	5.77	4.82	4.29	

Standard Error of Differences

two A means	$\sqrt{(2 \times E_a) / (r \times b)}$	= 0.954
two B means	$\sqrt{(2 \times E_b) / (r \times a)}$	= 0.317
two B (same A)	$\sqrt{(2 \times E_b) / r}$	= 0.635
two A (same B)	$\sqrt{2 [(b-1) \times E_b + E_a] / (r \times b)}$	= 1.086

E_a = error mean squared (A)

E_b = error mean squared (B)

t (0.25) = 2.372

L.S.D. = t x standard error

	L.S.D. (95%)
two A means	2.264
two B means	0.753
two B (same A)	1.506
two A (same B)	2.576

APPENDIX B

Grain dry weight 1989/90

r blocks	A	B	C
3	3	4	3

Correction Factor	358.61
Total SS	233.10
Whole unit SS	142.69
Blocks SS	52.73
A SS	55.76
B SS	20.60
AB SS	4.58
Total within units SS	48.12
C SS	21.78
AC SS	3.44
BC SS	1.05
ABC SS	2.68

Source	df	SS	MS	F
Blocks	2	52.732	26.366	3.08
A(Sowings)	2	55.763	27.882	3.26
Error(a)	4	34.191	8.548	
Whole unit total	8	142.687		
Within whole units				
B(Grazing treatment)	3	20.598	6.866	5.39***
AB	6	4.578	0.763	0.60
Error(b)	18	22.947	1.275	
Within units total	27	48.123		
Sub-subunits				
C(0 N, +N, clipping)	2	21.785	10.892	39.22***
AC	4	3.443	0.861	3.10*
BC	6	1.053	0.175	0.63
ABC	12	2.680	0.223	0.80
Error(c)	48	13.330	0.278	
Total	107	233.099		

1st Sowing	control	early	late	early/late	mean
nil N	1.43	0.46	1.09	0.83	0.95
plus N	1.79	0.62	1.30	1.15	1.21
clipping	1.43	0.24	0.52	0.22	0.61
mean	1.55	0.44	0.97	0.73	0.92

2nd Sowing	control	early	late	early/late	mean
nil N	2.18	1.97	1.31	1.22	1.67
plus N	4.16	2.79	2.35	1.48	2.69
clipping	2.18	0.99	1.13	0.56	1.22
mean	2.84	1.92	1.60	1.08	1.86

3rd Sowing	control	early	late	early/late	mean
nil N	2.90	2.21	2.33	1.98	2.36
plus N	4.05	3.35	3.05	3.15	3.40
clipping	2.90	2.16	1.95	2.15	2.29
mean	3.29	2.57	2.44	2.43	2.68

All Sowings	control	early	late	early/late	mean
nil N	2.17	1.55	1.58	1.35	1.66
plus N	3.33	2.25	2.23	1.92	2.44
clipping	2.17	1.13	1.20	0.98	1.37
mean	2.56	1.64	1.67	1.42	1.82

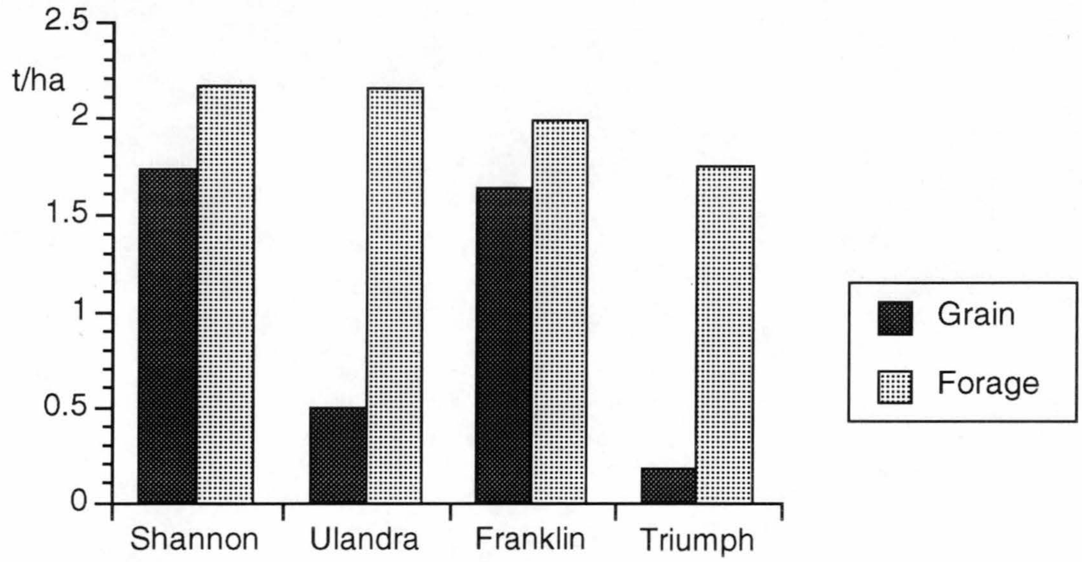
Standard error of differences, S.E. = $\sqrt{}$ (2 x error M.S.) / n
least significant difference, L.S.D. = t x S.E.

	L.S.D.	Sig. level	t	df	n(blocks)	Error M.S.	S.E.
A	1.47	95%	2.132	4	36	8.548	0.689
B	0.53	95%	1.734	18	27	1.275	0.307
C	0.21	95%	1.68	48	36	0.278	0.124
AC(A)	2.01	95%	1.68	48	12	8.548	1.194
AC(C)	0.87	95%	1.68	48	36		0.518

APPENDIX C

An experiment was set up on the Cressy research station by W.A. Vertigan and C.E. Young, Department of Primary Industry, Tasmania, in 1989/90 using four cultivars of barley sown on 22/3/1989. Each cultivar was clipped (sampled) three times to simulate grazing, 1) 15/5/1989, 2) 13/7/1989, and 3) 13/9/1989. Forage and grain yield results are presented below.

Grain and forage yields



Forage Removed